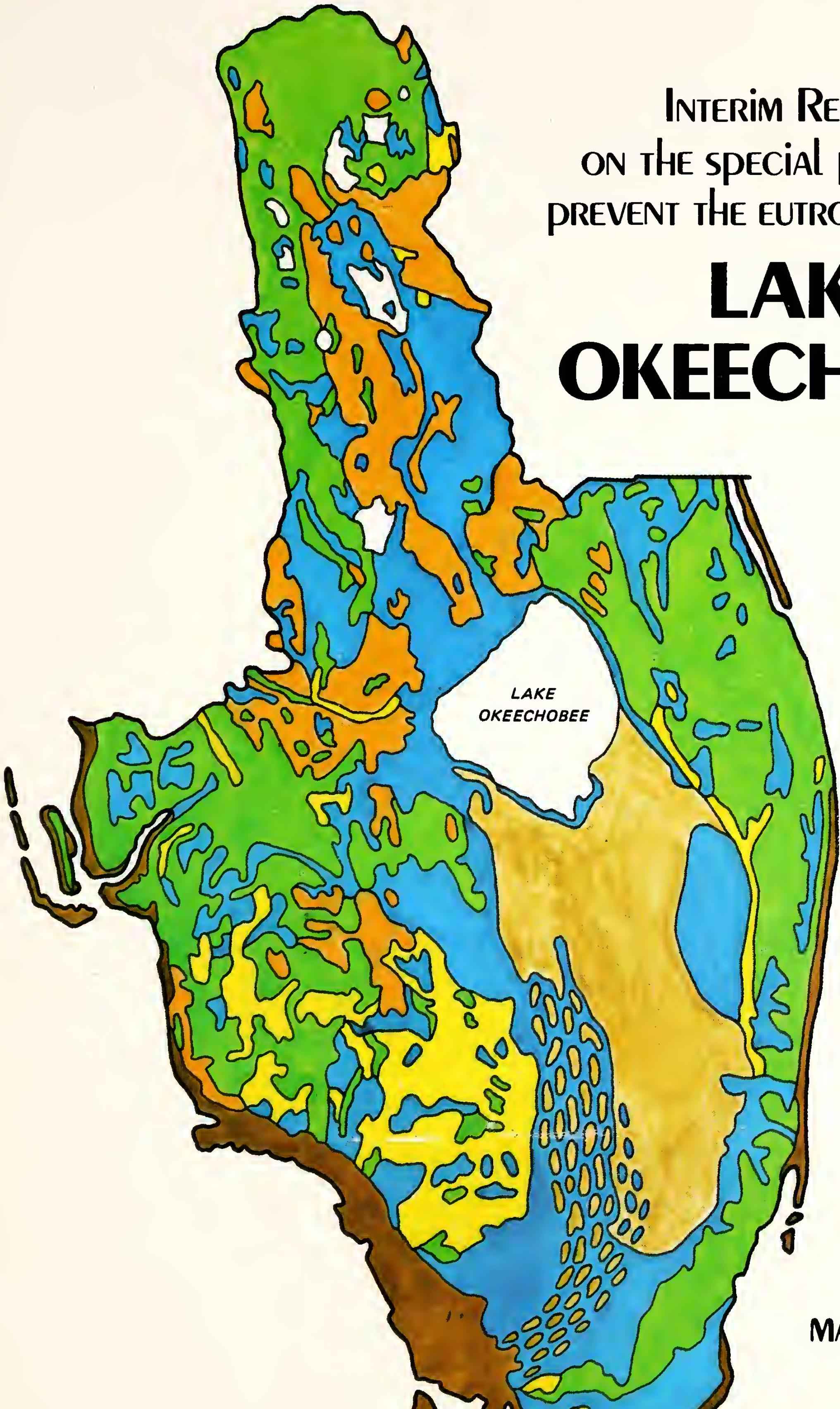
Interim Report on the special project to prevent the eutrophication of

LAKE OKEECHOBEE



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-Author's Note-

The findings and conclusions expressed in this report are preliminary and therefore subject to change. It also should be noted that interpretations given to data are from time to time debatable and not absolute. In a few instances, findings and conclusions presented herein are not held by all project participants but rather, represent results reflected in contracted research prepared on behalf of the project.

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TEXT

Not only will men of science have to grapple with the sciences that deal with man, but—and this is a far more difficult matter—they will have to persuade the world to listen to what they have discovered. If they cannot succeed in this difficult enterprise, man will destroy himself by his halfway cleverness.

—Bertrand Russell

SECTION I

INTRODUCTION

This report outlines progress of the *Special Project to Prevent the Eutrophication of Lake Okeechobee* (hereafter called the project).

Origin of the Project

Water quality and quantity problems have become prevalent and increasingly severe in South Florida since the early 1900's when extensive drainage and development began. In 1971, in recognition of the growing urgency, Governor Reubin Askew called a meeting of the Governor's Conference on Water Management in South Florida. The conference included more than 150 experts from scientific disciplines, government, agriculture, and conservation. Their report to the governor begins:

> *There is a water crisis in South Florida today.* This crisis has long-range and short-range aspects. Every major water area in the South Florida basin, Everglades National Park, the conservation areas, Lake Okeechobee and the Kissimmee Valley is steadily deteriorating in quality from a variety of polluting sources. The quantity of water, though potentially adequate for today's demand, cannot now be managed effectively over wet/dry cycles to assure a minimum adequate water supply in extended drought periods (Appendix A).

In mid-1972, the U.S. Geological Survey released a report entitled: *Chemical and Biological Conditions of Lake Okeechobee, Florida, 1969-1972.* The summary states: "The data obtained and evaluated during the investigation suggest that Lake Okeechobee is in an early eutrophic condition."

On November 15, 1972, the Central and Southern Florida Flood Control District released findings and recommendations based on public hearings concerning "alleged environmental damage resulting from channelization of the Kissimmee River." The first finding was: "It is abundantly clear from the testimony that the problems associated with the Kissimmee Basin and Lake Okeechobee (the lake already being in a state of early eutrophication) go far beyond the existing responsibilities of any single agency of government."

On December 12, 1972, a group of Florida scientists presented a report to the Governor and Cabinet sitting as the Board of Natural Resources, entitled: *The Kissimmee–Okeechobee Basin.** This report dealt with effects of the canalization of the Kissimmee River with implications for eutrophication of Lake Okeechobee. The report recommended that the Florida Cabinet take urgent action to prevent further degradation of Lake Okeechobee. This report and the Flood Control District's findings both recognized the fragmented and ineffectual nature of environmental management in South Florida and made recommendations for improvement.

The 1972 Florida Legislature enacted the *Florida Environmental Land and Water Management Act* and the *Florida Water Resources Act,* both considered to be landmark legislation for environmental protection. These laws provide much of the legislative framework necessary for wise use and management of Florida's natural resources.

The 1973 Legislature, in recognition of the significance of Lake Okeechobee and the magnitude of its problems, funded three state agencies to cooperatively carry out the *Special Project to Prevent the Eutrophication of Lake Okeechobee.* The Division of State Planning was charged with the overall planning, coordination, and report publishing; the Florida Department of Pollution Control with aspects dealing with data collection, water quality, and other problem analysis; and the Central and Southern Florida Flood Control District with data collection and certain aspects dealing with water quality and quantity and other problem analysis (Table 1).

Purpose of the Project

The ultimate purpose of the project is to understand the Lake Okeechobee ecosystem sufficiently to derive a land and water management plan which, when implemented, will prevent further cultural eutrophication of the lake. To achieve this purpose, it is necessary to analyze not only the lake as an ecological entity, but also the regional ecosystem of which Lake Okeechobee forms a dominant part. Objectives necessary to achieve these purposes are shown in Table 2. Table 3 shows progress to date and the tentative content of the final technical report.

Eutrophication is defined generally as enrichment of lakes by nutrients received from their watersheds. Lakes that are not eutrophic are called oligotrophic by lake scientists. The process of eutrophication is very complex and there is widespread confusion as to the meaning of the term, its causes and effects. The following are definitions of differ-

*Marshall, Arthur R., James H. Hartwell, David S. Anthony, John V. Betz, Ariel E. Lugo, Albert R. Veri, and Susan A. Wilson, 1972. *The Kissimmee Okeechobee Basin.* Division of Applied Ecology, Center for Urban and Regional Studies, University of Miami, Miami, Florida.

ent types of eutrophication as discussed in this report: (1) *Natural eutrophication* occurs in lakes that receive nutrients sufficient to cause enrichment or "over-fertilization" from the fertile watershed in which they reside. This takes place as the result of natural processes working on the watershed. The rate and amount of nutrient inflow necessary to cause eutrophication depends on many complex factors including a lake's ability to absorb and utilize nutrients and its ability to export part of its nutrient load. Natural eutrophication normally takes place over long time periods. Naturally eutrophic lakes have high production rates of plant and animal life which are fueled by the abundant nutrient supply. In Florida, such lakes are characterized by extensive zones of rooted or floating aquatic vegetation, somewhat degraded water quality and by short periods of algae blooms and fish kills. Normally both sport and commercial fishing are good in a naturally eutrophic lake. (2) *Cultural eutrophication* is the term used to describe the enrichment process caused by nutrients that result from poor land use and drainage practices in the watershed and/ or nutrients introduced in sewage or industrial wastes. Today, cultural eutrophication, caused by man, is by far the most prevalent type of eutrophication and can occur in a very short period of time. In some cases, cultural eutrophication is accompanied by other types of pollution such as pesticides, heavy metals, viruses and bacteria and other substances. Since cultural eutrophication occurs in much less time than natural eutrophication, it normally results in greatly accelerated plant and animal production and expresses more pronounced negative effects such as water quality degradation, taste and odor problems, algae blooms, fish kills, and loss of sport fish. (3) *Hypereutrophication* results when the eutrophic process advances to the point where the periodic short-term undesirable traits associated with natural eutrophication and magnified in cultural eutrophication become increasingly severe and prevalent to such an extent that they become the lake's dominant characteristics. This condition destroys virtually all amenity values and in Florida results in a severe decrease of sport fish, renders the water odoriferous and undrinkablewithout extremely costly treatment, may be accompanied by human health problems and always results in sustained algae blooms and noxious weed problems. The onset of hypereutrophication is rapid, unlike the more gradual transition from oligotrophic to eutrophic states. The prime example of hypereutrophication in Florida is Lake Apopka, a 36,000 acre lake whose watershed is contiguous to the Lake Okeechobee watershed.

The Organization of Project Research

For necessary understanding of the complex ecology of Lake Okeechobee, project research has been designed and is now well advanced to investigate the lake and each of its subdrainage basins. Water and nutrients entering the lake are being measured and related to land use and drainage practices in each of the lake's sub-basins. This information is being integrated with knowledge of the lake's present level of eutrophication. Downstream areas are being studied to determine how various methods of preventing further eutrophication would affect these areas which depend on the lake for water. This research is discussed in Section II of this report.

In Section III, studies of the ecological and economic processes that integrate the subdrainage basins, the lake and the downstream areas into the highly unified South Florida regional ecosystem are discussed. These integrative studies will allow evaluation of the effects of present and alternative management programs on the regional ecosystem.

The project has also investigated the legal and administrative aspects of management for water quality. This research is well advanced and is discussed in Section IV. Results will be integrated into the management plan being developed by the project. In this manner the goals, management recommendations and legal and administrative mechanisms for effective implementation, will be integrated into a comprehensive management plan for the South Florida basin.

The project is presently in that phase of study where research, analysis, and computer modeling are not yet complete. Therefore, findings and conclusions of this report are preliminary. Section V discusses the evolving perspective as indicated by the now voluminous scientific literature on South Florida and the ongoing research of this project. The project's final reports will consist of technical findings and conclusions and a comprehensive management plan for the prevention of further cultural eutrophication of Lake Okeechobee and more optimal regional management.

Computer modeling of the South Florida regional ecosystem began in an organized manner in 1971 when comprehensive models of the various component ecosystems were developed to integrate information and knowledge on the many various ecological aspects of the regional ecosystem.* In May, of 1973, the U.S. Department of the Interior and the Division of State Planning agreed to jointly undertake phase two of the South Florida Environmental Study, now approaching completion; and in 1973, the Florida Legislature initiated the research and planning study discussed in this report. Both studies are designed to derive techniques and policy for effective resource management of portions of South Florida. This period of intense study has clearly entered the phase where management alternatives have been identified and partially evaluated.

There is much work to be done between now and project completion when the initial management plan will be presented and much to be done afterwards to implement that plan. Full achievement will take years of work and change. Continuous monitoring, analysis, modeling, and planning, in response to feedback from the natural and societal systems involved, will be necessary to reverse the present long-term degradation trends and conditions that exist in Lake Okeechobee and South Florida.

*Lugo, Ariel E., Samuel C. Sneadaker, Suzanne Bagley, and Howard T. Odum, 1971. *Models for Planning Research for the South Florida Environmental Study.* University of Florida, Gainesville, Florida.

Significance of Lake Okeechobee

The significance of Lake Okeechobee to the health and vitality of South Florida can scarcely be overestimated. Lake Okeechobee is the dominant entity upon which virtually the entire region depends for freshwater during droughts that occur periodically in South Florida. During prolonged drought, the lake is the major source of recharge Fn for the Biscayne aquifer, presently the only source of water for the approximately 2.25 million people living in Dade and Broward Counties.

Under average conditions, recharge of the Biscayne aquifer is primarily by rainfall. During the dry season, however, and Fn especially during extended drought, recharge takes place in the water conservation areas and along the numerous drainage canals that dissect the Gold Coast. Water for recharge is supplied from Lake Okeechobee.

Overdrainage with resultant lowering of water levels in the aquifer caused salt-water intrusion for varying distances inland in the Miami area beginning in the early 1910's. Salt-intrusion control structures greatly retarded this trend from 1946 to the present; however, the only adequate method for stopping salt intrusion is to maintain sufficient fresh water in the Biscayne aquifer to curtail the inward movement of salt water (Hartwell et al., 1973). During drought, Lake Okeechobee supplies this water.

During the latter portion of the 1971 drought, *the Miami Springs well field was directly dependent on Lake Okeechobee for recharge water delivered via the Miami Canal* (Hartwell et al., 1973). This well field supplied 70 percent of the water for domestic purposes in Dade County. The average daily municipal pumpage from the aquifer in 1970, was estimated to have been 250 million gallons per day (mgd), an increase of approximately 190 percent from the 130 mgd used in 1950. Drought conditions in the spring of Fn 1975 again resulted in releases, beginning in early April, of water from Lake Okeechobee to Dade County through the Miami Canal. Releases were necessitated to recharge the Biscayne aquifer and to retard saltwater intrusion. *It is vital to Broward and Dade Counties that recharge for the Biscayne aquifer be available from Lake Okeechobee and that water should be of high quality.*

Present indications are that water imported from Lake Okeechobee to the Biscayne aquifer via Flood Control Project canals and the water conservation areas plays an increasingly important role in the total flow of the area. Lake Okeechobee, in this respect, is truly the "liquid heart of South Florida."

Florida is now the number one state in population growth with a net gain of approximately 7,500 people each week. Many of the fastest growing counties are in South Florida, and should Lake Okeechobee which is moderately eutrophic, become hypereutrophic, severe problems will arise.

Im

Hypereutrophication related to sewage inputs greatly increases the likelihood of disease from bacteria and viruses. Even when there are no pathogenic organisms present, hypereutrophication presents a number of problems and undesirable effects in terms of potable water supply. If Lake Okeechobee continues to deteriorate, treatment of drinking water for surrounding communities will prove to be more costly. Most surface waters require some treatment before consumption and hypereutrophication greatly increases costs of producing potable water.

In addition, hypereutrophication would result in chronic and pronounced negative effects such as water quality Im degradation, taste and odor problems, algae blooms, fish kills, and noxious weed problems. These characteristics which are now expressed by the lake periodically on localized or short-term basis, will become the predominant characteristics of the lake, should hypereutrophication take place.

Lake Okeechobee is as important to nature in South Florida as it is to man. Under present management, water level fluctuations in the lake maximize the amount of marsh that is alternately inundated and dried, and this type marsh is a prime feeding area for wading bird populations.

Preliminary work by Browder (1974) indicates that the present area of approximately 120,000 acres of seasonal marsh in Lake Okeechobee could be significantly reduced under present plans to raise the dike and subsequently to raise the lake level by 2 feet. If this analysis proves accurate, it would jeopardize wading bird populations, particularly the Wood Stork, whose survival is presently marginal (Browder, 1974). In addition, the loss of a large amount of marsh could also have a severe negative effect on IIm the eutrophication of the lake (Gayle, 1975).

Both man and nature in South Florida depend on Lake Okeechobee's water storage capacity for a wide variety of life-support and enrichment services. Wildlife values of the lake are very high for species other than wading birds, including several endangered species such as the Bald Eagle, the Everglades Kite, and others. Recreation and other amenity values of the lake are great as well. A large part of the southern portion of South Florida receives some portion of its water budget from the lake. The regional ecosystem has a very real dependence on Lake Okeechobee and, naturally, so has man's systems as well. The water quality and consequent health of the lake is critical to the future of South Florida and should be of vital concern to all Floridians.

In 1971, the report of the Governor's Conference on Water Management in South Flordia said: "recognizing that Lake Okeechobee is the hub of water quantity and quality in South Florida, the most important and overriding consideration should be not only to maintain the present quality of the lake, but also to improve it."

SECTION II

ECOLOGICAL STUDIES OF LAKE OKEECHOBEE AND ITS DRAINAGE BASIN

Ecology as defined by Webster is the "totality of patterns of relations between organisms and their environment." This concept of the unity of life and environment is one of history's basic themes. Combined with man's growing understanding of systems as interacting and interdependent parts of a unified whole, the concept of ecological unity led to the formulation of the concept of ecological systems or "Ecosystems." Large ecosystems include man, nature and environment, joined together in a functional unity. Unfortunately, many people are not aware that man depends on nature for conditions that support life as well as for resources.

The main value of the ecosystem concept is its emphasis on interrelationships of the parts of the whole. Because parts are inseparable from the whole, the application of systems analysis and management techniques are most appropriate for solving the urgent problem of environmental management for the regional ecosystem.

Successful development of a plan to prevent the further cultural eutrophication of Lake Okeechobee depends on understanding: (l) the regional ecosystem, (2) the basic functional and structural characteristics of the 730 square-mile lake, and (3) adjacent subdrainage basins that together form the Lake Okeechobee drainage basin (Fig. 1). Lake Okeechobee receives water and nutrients from the following subdrainage basins: (1) Kissimmee River Basin (Canal-38 and the Kissimmee Upper Chain of Lakes), (2) Taylor Creek- Nubbins Slough Basin, (3) Fisheating Creek Basin, (4) Lake Istokpoga Basin, and (5) the Agricultural Area.* Upstream drainage basins must be managed so as to restrict nutrient runoff levels to below the safe assimilative capacity of Lake Okeechobee.

In the same way that Lake Okeechobee is coupled to upstream basins and the Agricultural Area by water, nutrient flows and other ecological relationships, the lake is also coupled to downstream areas that receive water and nutrient flows from it. Downstream subsystems receiving flows from Lake Okeechobee are: (1) the St. Lucie Canal and estuary, (2) the Caloosahatchee River and estuary, (3) the water conservation areas, (4) the Biscayne Aquifer, (5) the Miami, Hillsboro, North New River, and West Palm Beach Canals, (6) the urbanized Gold Coast, (7) Biscayne Bay, (8) Everglades National Park, and (9) the Gulf of Mexico. Downstream areas are part of the regional ecosystem of interest since management techniques that affect Lake Okeechobee will directly affect downstream areas.

*The Agricultural Area, south of the lake, is "backpumped" by pumps operated by Central and Southern Florida Flood Control District. Backpumping consists of pumping wet season water from a portion of the Agricultural Area up an average gradient of one foot to get the water into Lake Okeechobee. The average yearly volume of water backpumped into the lake is 350,000 acre ft.

Lake Okeechobee, its drainage basin, and the downstream areas that compose the South Florida regional ecosystem are shown in Figure 1. Figure 2 shows primary canals of the Central and Southern Florida Flood Control Project and private secondary canals that dissect the South Florida Region. The total Lake Okeechobee watershed contains 4,500 square miles.

Before drainage modification, during wet seasons, water overflowed the southern lake shore and traveled slowly southward to reach the northernmost portion of the "River of Grass" Everglades. Overland flow through the luxuriant sawgrass and other marsh vegetation was down a slope that was nearly imperceptible. Thick vegetation and gentle slope resulted in flow characteristics resembling those of a permeable aquifer rather than surface flow of a shallow forty-mile-wide river. As vegetation is less dense in the southern Everglades, overland flow southward to the Gulf of Mexico became more rapid in that area (Leach et al., 1972).

Lake Okeechobee

Lake Okeechobee's earliest recorded name was "Mayaimi." The Miami River and City of Miami received their names as a modification of that Caloosa Indian word which means "Big Water." This emphasizes the intimate functional relationship between the lake and the Everglades as the lake's original name became permanently fixed far to the south because principal access to the lake was by the Miami River and a canoe trail through the Everglades to a blind river and finally to Lake Okeechobee. Okeechobee, a Seminole name, also signifies "Big Water" (Brooks, 1974).

In 1866, the map-maker Angelo Heilprin visited Lake Okeechobee and his description presents one of the best pictures of the nature of Lake Okeechobee before modification:

> The lake proper. is a clear expanse of water, apparently entirely free of mud shallows, and resting...on a firm bed of sand. All our soundings and drags indicate that this sand is almost wholly destitute of aluminous matter, and nowhere, except on the immediate borders, where there is a considerable outwash of decomposed and decomposing vegetable substances, is there a semblance to a muddy bottom. The water itself, when not disturbed is fairly clear, and practically agreeable...More generally, however, it is tossed into majestic billows, which rake up the bottom, and bring to the surface a considerable infusion of sand, rendering the surface murky.

Heilprin's description of the effects of the wind on Lake Okeechobee applies today. Complete vertical mixing is effected because the average depth of the lake is less than 9 feet and the average wave heights are about 1.4 feet. The lake is violently agitated under storm conditions and the bottom substrates are thoroughly scoured. For this reason

detrital material is cast out and loose sand is scarce on the bottom (Parker et al., 1955).

Before drainage, during annual wet seasons, lake levels rose to inundate the low plains and prairies surrounding the lake. Water overflowed at two places along the southern shore when levels reached about 15 feet mean sea level (MSL). Water also overflowed westward into Lake Hicpochee and the headwaters of the Caloosahatchee River. Overflow along the southern shore became general at a level of about 18 feet and sizable quantities of water flowed southward out of Lake Okeechobee (Leach et al., 1972).

Lake Okeechobee is now completely diked and all outflows are controlled, as are all inflows except those of Fisheating Creek. Table 4 shows the percentage of total nitrogen, phosphorus and water inflows to the lake and tons of nutrient inputs. Table 5 shows volumetric nutrient loadings to the lake. Increased runoff carrying large nutrient loads caused by upland drainage and agricultural development is presently conveyed by canalized and channelized waterways from the sub-basin directly to Lake Okeechobee. Also, the lake is no longer able to export excess nutrients southward to the Everglades as described by Heilprin, and as illustrated by the enormous quantity of organic soil that existed south of the lake. Nutrients generated in the northern portion of the organic mucklands south of the lake are now pumped with wet season runoff back into the diked lake. Fish kills, algae blooms and degraded water quality have been and are being experienced as a result of cultural eutrophication caused by nutrient laden waters entering from various tributaries.

Computer Model Studies of Lake Okeechobee by the Wetlands Center of the University of Florida

On February 22, 1974, as part of the project, the Florida Department of Pollution Control funded the Wetlands Center of the University of Florida to develop analog computer models of Lake Okeechobee. Principal investigators are Dr. H.T. Odum, Dr. Frank Nordlie, and Mr. Timothy Gayle.

Research Procedure

Given the project's purpose of preventing the further cultural eutrophication of Lake Okeechobee, a process clearly nutrient induced, the primary research questions relating to the lake itself are: (1) what are the eutrophic effects of present nutrient loads? (2) what is the safe nutrient loading as determined by the lake's assimilative capacity over time? and (3) what management techniques are available to increase the assimilative capacity of the lake and/or decrease nutrient loads?

In order to answer these questions, a model was developed to simulate the overall functions of Lake Okeechobee. Data utilized in the model include rainfall, storage volumes, inflow rates and volumes, water quality and nutrients, amounts and kinds of fish and vegetation, and other variables. Data were collected from all available sources including the Florida Game and Fresh Water Fish Commission, the Central and Southern Florida Flood Control District, the U.S. Geological Survey, the U.S. Army Corps of Engineers, and the Department of Pollution Control. The Lake Okeechobee model also accepts calculations from other models being developed by the project and discussed later in this report. Actual simulations of the hydrologic and nutrient components have taken place although calibration is still going on. Simulation of other aspects will begin in the near future.

Results and Discussion of the Lake Okeechobee Model Study*

These tentative conclusions are based upon incomplete data and analysis and, in general, are without the benefit of simulation and should be used solely for preliminary understanding. Research and simulations will deal conclusively with the eutrophication of Lake Okeechobee and its prevention.

The original phosphorus levels in the lake appear to have been relatively low, especially for Florida, judging by a few measurements of total phosphorus made in Lake Okeechobee in 1952 and before. Shallow lakes such as Okeechobee are relatively more eutrophic than are deeper lakes, other properties being the same, since the productivity of a shallow lake is concentrated in a smaller volume of water. Compared with some lakes, Lake Okeechobee was originally moderately fertile, and early harvest of commercial fisheries recorded by the Game and Fish Commission probably bear this out.

Since the early part of the century, water hardness has increased in Lake Okeechobee. This change is tentatively traced to increasing groundwater inflows as tributaries to Okeechobee have been receiving more groundwater because of canalization and channelization. Nutrient levels in the lake have increased somewhat since 1952, due to fertile runoff from human settlements, agricultural development, backpumping of water from the Agricultural Area, and possibly from scouring of the bottoms of associated waterways when water levels in them were reduced by present water management.

A preliminary model of nutrients has been simulated. The preliminary simulations suggest an important role for marsh vegetation, muds, and lake bottom snails in holding phosphorus and recycling it in regular exchange with the water. These storage and recycling mechanisms keep the lake's metabolism and other responses more stable than they would be otherwise.

*This section was abstracted directly from Odum, et al., 1974. *Water Quality Models for Understanding Potential Eutrophication in Lake Okeechobee, Florida.* Center for Wetlands, University of Florida, Gainesville, Florida.

Against All ODDS

The rate of biological productivity and the state of eutrophication is to a great extent affected by the quantity of nutrients flowing through the lake ecosystem. Since the lake has a high alkalinity (pH 8.4) and calcium content (44ppm), the solubility of phosphorus is low and phosphorus in turn limits the growth of phytoplankton; however, should phosphorus loading into the lake increase, or the alkalinity be lowered by additions of organic matter in water from the Agricultural Area or from an inundation of marsh plants under proposed new lake regulation, then phosphorus levels and phytoplankton activity in the water column would increase. Conversely, if the loading rates were reduced, the model suggests that the phosphorus in the water column (algae and dissolved phosphorus) would be reduced proportionately. Up to 5.77 grams of carbon per square meter of area per day (gm C/M3-day) of gross primary production have been measured in the pelagic zone, averaging about 2.1 gm C/M3-day of gross primary production. *This condition is considered moderately eutrophic and,as the model implies, is strongly affected by the nutrient loading rates from the lake's tributaries.*

lag time

The model suggests that for all aspects of the lake to respond and adjust to increased levels of nutrient inflow requires a ten year period. Simulation shows that when further nutrient increases are applied in the model, increased nutrient levels in most of the lake's characteristics would occur within 10 years.

Empirical analysis of actual water quality data leaves no doubt that Lake Okeechobee is presently moderately productive and moderately eutrophic. Frequent algae and zooplankton blooms caused by algae species indicative of eutrophy have been observed in deep water areas. From these facts the inference is made that the lake is enriched and eutrophic. In addition, recorded high primary production values unmistakably indicate Lake Okeechobee to be eutrophic. Since most of the observations of fish kills have been limited to the rim canal and immediate periphery of the lake, low oxygen problems have not become general in the lake's open waters, although some low values have been recorded. *This indicates that eutrophy is not in the most advanced stages, but that great care should be taken in the management of the lake.*

Lake Okeechobee's littoral and marsh zones, in contrast to most large lakes, are extremely important in their capacity to absorb nutrients from the water and to fix and store energy. The controlled levels of the lake in turn determine the size of the marsh and littoral zones, and consequently have drastic effects on water quality, energy flow, and total productivity. These factors must be evaluated when proposals for water level changes for Okeechobee are considered. In addition, the marshes provide extremely productive habitat for birds, fish, bottom fauna, and other wildlife.

Preliminary modeling suggests that if bacterial decay rates are as fast in Lake Okeechobee as normal rates for other warm water lakes, no critical bacterial problem exists at present. Inflows of bacteria would have to be much greater than those presently recorded before high quantities of bacteria with the potential of affecting man would develop. Data will be obtained to permit more accurate statements regarding bacterial levels in the final report.

Because hydrologic flows are vital to the management of Lake Okeechobee, the hydrologic aspects of the overall model have been studied separately for clear understanding of the large hydrologic flows and processes that act as a controlling factor on the lake. Some of the more important features of Lake Okeechobee hydrology are presented in Figure 3. The principal contributors of water to the lake are rainfall (45.6 inches or 1,751,000 acre-feet per year) and the Kissimmee River (1,534,000 acre-feet per year), both of which contribute maximal flow in the late summer and fall. Other surface runoff provides around 500,000 acre-feet of water per year. The principal water losses from the lake are evapotranspiration (2,138,900 acre-feet per year) and discharge through the drainage canals (1,680,000 acre-feet per year). Throughout most of the year, evaporation exceeds rainfall and the lake must have surface runoff to maintain its level. An average of over a million acre-feet of water is normally discharged from the lake to the sea each year since runoff from the Kissimmee River and other sources is usually more than enough to counter evapotranspiration in the lake. This annual discharge and the associated deleterious effects on the estuaries should be considered in management evaluations.

The lake level is generally lower than actual regulation levels established by the Corps of Engineers during the design and construction of the Flood Control Project. The lake has been below 11 ft. (MSL) several times in the last decade. Since the lake level exerts a tremendous influence on marsh productivity and on the gravity flow of water to the south,the timing and time span of potential lake levels must be evaluated carefully for optimum ecological and agricultural production and ability to supply water to the urban Gold Coast.

Changes in the hydrology of the lake may be due, in part, to the channelization of river basins to the north, as is suggested in Figure 3 . Data suggests that before channelization the Kissimmee River Basin had longer retention times and greater water storages than the present canalized basin. The property of greater retention and storage induced lower flood peaks, greater base flow, and generally less variable flows for the same rain conditions. Consequently, this more stable hydrologic input from the Kissimmee River would cause Lake Okeechobee to rise less quickly in a flood, drop less quickly in a drought, and possess more stable levels and greater ease in regulation. Simulation suggests the flood control system has drastically decreased surface water storage in the Kissimmee floodplain and the Everglades, resulting in flow rates that are much more variable than under natural conditions.

Preliminary simulations of the hydrologic model indicate that rain and river inflow to Lake Okeechobee, combined with outflow to the Caloosahatchee and St. Lucie Canals and evaporation, provide inflow-outflow quantities sufficient to replace the volume of water in the lake about once a year. Simulation of the Agricultural Area water inputs to Lake Okeechobee shows wet season backpumping from the Agricultural Area causes additional stress on regulation facilities by increasing water loads to the lake during peak flow periods.

Work on the Lake Okeechobee model is progressing rapidly at this point. All component models have been developed

and reviewed and quantitative evaluations are being completed as rapidly as data become available. *Present evidence unmistakably indicates Lake Okeechobee to be moderately eutrophic and that great care should be taken in the management of the lake to lessen nutrient inputs to the lake and to facilitate the lake's assimilative capacity to absorb nutrient loads.*

Analysis of the Effects of Backpumping from the Agriculture Area on Water Quality of Lake Okeechobee

The Florida Department of Pollution Control funded Dr. Patrick Brezonik of the Department of Environmental Engineering Sciences of the University of Florida on June 21, 1974, to analyze the effects of backpumping wet season water from the Everglades Agricultural Area into Lake Okeechobee.

Research Procedure

Agriculturally valuable muckland south of Lake Okeechobee has been drained by canals and, during the summer wet season, drainage water is often pumped against the natural southerly gradient and into the lake (Fig. 4). Objectives of this study were: (1) determination of the quality of backpumped agricultural drainage waters with particular reference to nutrient contents, (2) preliminary identification of major point and non-point pollution sources, and (3) assessment of the impact of the backpumped water on water quality in Lake Okeechobee.

The effects of drainage water from agricultural mucklands near Belle Glade on water quality in Lake Okeechobee were examined in an extensive synoptic survey during August, 1974. This study was undertaken in a cooperative effort by the Florida Department of Pollution Control (DPC) and the Department of Environmental Engineering Sciences (EES) of the University of Florida. DPC was responsible for sampling site selection, sample collection and field analyses. EES did the laboratory analyses and assembled and interpreted the data.

A total of 52 sampling stations were established by DPC within the drainage canals and the southern end of Lake Okeechobee near the Flood Control District Pumping Stations 2 and 3 and the city of Belle Glade. Water samples were taken from the 52 sampling stations by DPC on August 5-6, 1974. All samples were placed on ice and shipped to the laboratory where analyses of nutrient forms were completed within 72 hours of sample collection. Data such as water temperature, dissolved oxygen, pH, specific conductance and depth were taken at all stations.

Results and Discussion of The Study on Effects of Backpumping from the Agricultural Area on Water Quality in Lake Okeechobee*

The Flood Control District Pumping Station No. 2 near Belle Glade removes drainage water from approximately 180 square miles of the Everglades Agricultural Area. This pumping station was constructed in 1957 and has a capacity to pump 2,327 million gallons per day (mgd). Pumping Station No. 3 removes drainage water from 129 square miles, was constructed in 1958 and has a capacity of 1,667 mgd (Fig. 5).

During the sampling period extremely high nutrient levels (with the exception of nitrate) were found at all sampling stations in the Hillsboro Canal. Table 6 presents mean values and ranges for the chemical analyses.

The mean ammonia and color levels found in the Hillsboro Canal exceed the U.S. Environmental Protection Agency (EPA) permissible criteria for public surface water supplies. Conductance and fluoride values in the canal exceed the Florida State Pollution Standards, while dissolved oxygen concentrations were below the minimum for both standards. Nitrate, iron, and chloride all exceed desirable criteria established by EPA.

Figures 6 and 7 depict the changes in some of the biogenic parameters in the canal as the water is pumped into the lake. There is a general increase in total soluble phosphate from 0.22 milligrams per liter in the canal section draining the southeastern agricultural areas to a maximum of 0.38 milligrams per liter at the northern limits of Belle Glade. This trend implicates both the City of Belle Glade and the southeastern agricultural areas as major contributors of soluble phosphate to the canal, but because of the one-time nature of the sampling, definitive conclusions on this subject are not possible.

The North New River Canal was being backpumped in conjunction with the Hillsboro Canal during the sampling period. Except for nitrate, the nutrient levels in the North New River Canal were generally lower than the Hillsboro Canal, though still relatively high (Table 7). Conductance values for the North New River Canal exceed Florida State Pollution Standards. Permissible criteria established by the EPA are exceeded by color and ammonia while desirable criteria are exceeded by iron and chloride. Dissolved oxygen concentrations are lower than the minimum values established by both of the above agencies. Manganese concentrations also exceed USPHS Standards.

Figure 8 illustrates trends in the different phosphate species found in the canal. The level of total soluble phosphate decreased markedly proceeding northward up the canal, but

*This section was abstracted from Brezonik , P.L. and A.Fredrico, 1975. *Effects of Backpumping from the Agricultural Area on Water Quality in Lake Okeechobee.* Department of Environmental Engineering Sciences, University of Florida, Gainesville, Florida.

levels of total ortho, and particulate total phosphate notably increased. The increase in total phosphate may be related to inputs from the town of South Bay and the immediate surrounding area.

Nitrogen concentrations (Fig. 9) remained high and relatively constant in the canal,suggesting the agricultural areas south of South Bay as major contributors of this nutrient to the canal. Values for the other parameters are generally lower than those found in Hillsboro Canal but remain relatively high and constant, implicating the agricultural areas as their source.

In contrast to the Hillsboro and North New River Canals, the Miami Canal was not backpumped during the sampling period and there was no flow indicated in the canal. Water in the Miami Canal was of considerably better quality than that of the Hillsboro Canal and the same or slightly better than that of the North New River Canal. Because of the static nature of the canal at the time of sampling, identification of potential sources of pollution was not possible. Variations in biogenic parameters could reflect biological activity within the canal rather than input sources. Water quality in drainage canals is said to decline rapidly under backpumping conditions; the already poor water quality in the Miami Canal during the sampling time suggests that backpumping was a recent occurrence. Conditions probably would not decline drastically under backpumping conditions.

Figure 10 clearly indicates that backpumping causes elevated conductance (hence dissolved solids) throughout the south end of the lake. Values are highest in the Rim Canal and South Bay and compare closely with the values in the drainage canals themselves. Values decline slowly to the north but are still elevated as far north as Kramer Island. Stations 7, 21, 32 and 58 approach conductance levels at the north end of the lake in early September (Table 8), and probably reflect "average" conductance values for the lake during this period. Similar trends were found for fluoride, total organic carbon (TOC) and color distributions (Figs. 11, 12, and 13, respectively). Backpumped waters were high in these constituents and elevated levels occurred throughout the southern area of the lake.

Figures 14 and 15 illustrate the distribution of phosphate in and around the southern shore of Lake Okeechobee. In general, the distribution of orthophosphate reflects the influence of the backpumped water entering the lake. Specifically, orthophosphate (Fig. 14) was relatively high in the shore areas, especially near S-2, and relatively lower in the open waters. The Rim Canal, which receives the brunt of the backpumped waters, had the highest orthophosphate concentrations in the lake. Total soluble phosphate (TSP) likewise was higher in the Rim Canal than in the open lake (Fig. 15). Trends in TSP within the open lake were less dramatic, but near-shore and South Bay waters had generally higher levels than water to the north.

It appears evident from Figures 16-19 that the Rim Canal bears the brunt of the nutrient load imposed on Lake Okeechobee by backpumping. The canal appears to function in a buffering capacity by dispersing the nutrient load along a large area of the southern lake shore, thus reducing localized problems.

In summary, water quality in Lake Okeechobee apparently has been declining for many years, and the lake is now best described as moderately eutrophic (rich in nutrients). The sources of these nutrients (mainly nitrogen and phosphorus) are many, including sewage effluent from towns around the lake shore and on upstream tributaries. Of probably greater importance for Lake Okeechobee, however, are "non-point" nutrient sources, primarily runoff from agricultural (crop and pasture) land. Development of a complex network of drainage canals in the lake's watershed to allow farming on once marshy land has accelerated nutrient loss from the land and input to the lake. The drainage network has also increased the lake's watershed by over 1000 km^2 (400 mi^2).

The effects of the abundant nutrient supply on Lake Okeechobee have been to increase the growth of algae to bloom proportions, thus reducing water clarity, and to enable aquatic macrophytes to proliferate to nuisance proportions. Floating mats of hyacinths are already a common sight on the lake, and littoral areas at the south end of the lake are becoming clogged with submerged vegetation. *Water quality in Lake Okeechobee has not degraded to the hypereutrophic state of other Florida lakes like Apopka, but trends of increasing nutrient loading from the drainage and land use practices clearly point in that direction. The importance of Lake Okeechobee as a water supply for highly populated South Florida requires that steps be taken to protect and manage this resource properly.*

Results and Discussion by the Central and Southern Florida Flood Control District in their Lake Okeechobee-Kissimmee Basin Water Quality Study

Studies by the Central and Southern Florida Flood Control District on nutrient loading of Lake Okeechobee have indicated several conclusions relevant to nutrient input to the lake. The District, in its March 20, 1975, report (see Appendix B), concludes that:

1. Nutrient concentrations of the Kissimmee River inflows are less than the concentrations of any other inflow, except precipitation.

2. The percentage of Fisheating Creek's and Kissimmee River's contributions to total nutrient loading is closely related to their water flow contributions.

3. The contribution of phosphorus from Taylor Creek-Nubbin Slough is disproportionately high in relation to its flow contribution; being equal to or greater than that from the Kissimmee River with only 10%-20% of its flow.

4. The contribution of nitrogen from the Agricultural Area (S-2 and S-3 is disproportionately high in relation to its flow contribution; being about equal to that of the Kissimmee River with only about 25% of its flow [1973-74 data]).

5. The Taylor Creek-Nubbin Slough and S-2/S-3 data, together with that from C-40/C-41, indicate a definite relationship between type of agricultural land use, soil type, and character of the nutrient loading. The highest phosphorus concentrations and loadings are found in an area used intensively for dairy farming, and next highest in an area (C-40/C-41) largely devoted to pasture. The highest nitrogen concentrations and loadings derive from a muckland area devoted to row crops and cane.

6. There has been no basic change in the chemical water quality of the lake in the five-year period, nor have there been any material values from the various contributing sources, with the possible exception of the phosphorus loading from the Indian Prairie area (C-40/C-41).

7. Water inputs to the lake from direct precipitation are roughly equivalent to inputs from the Kissimmee River, and total nutrient loads from that source are approximately half of that from the Kissimmee River.

The Lower Kissimmee River Valley

Historically, the Kissimmee River Valley was the northernmost part of the pristine Everglades (cover). Wet season water flowed through the Upper Kissimmee Chain of Lakes southward through ninety miles of the winding Kissimmee River into Lake Okeechobee. The Kissimmee River floodplain averaged over a mile in width and supported luxuriant marshes that, in turn, supported large fish and wildlife populations. When wet season water from the Kissimmee and other tributaries filled Lake Okeechobee, the lake overflowed, contributing water to the Everglades south of the lake and ultimately to the Gulf of Mexico some 100 miles further south.

The Kissimmee River was extraordinary by any criterion. On December 29, 1899, the *Kissimmee Valley Gazette* newspaper said of the river;

> ....in its narrowness, the rampant growth of water plants along its low banks, in the unbroken flatness of the landscape, in the variety and quantity of its bird life, in the labyrinth of by-channels and cutoffs, and dead rivers that beset its sluggish course, and above all in the appalling, incredible bewildering crookedness of its serpentine body. There are bends where it has taken nearly an hour's steaming to reach a spot less than 100 yards ahead of the bow. On either side, as far as the eye can reach lies the prairie dotted with small hammocks. Occasionally, the bank rises a few feet to a ridge or hammock and here the steamers make a landing.

Natural drainage in the Kissimmee Valley was principally downward into the deep sandy soils. In uplands of the valley, the ground water table fluctuated several feet between wet and dry seasons. Ground water was very stable and near the land surface in the river floodplain and other low areas during both wet and dry seasons and during all but the longest drought. Water was stored in the water table that, during dry season and drought, was available to the ecosystem as base flow from the shallow aquifer into surface waters and lowland marshes. This water-storage function of the natural ecosystem resulted in patterns of many lakes, marshes, wet prairies, and ponds (Fig. 20).

Drainage of the basin was begun in the 1880's by Hamilton Disston who purchased 4,000,000 acres of South Florida from the state at 25 cents per acre. The state also promised Disston one half of all additional lands he could "drain" (see Appendix C). Drainage of the Upper Kissimmee Valley was begun by dredging channels to connect the major lakes of the Kissimmee Upper Chain of Lakes to lower their levels by increasing flow southward to the Kissimmee River. The Kissimmee River's winding channel was also dredged from Lake Kissimmee to Lake Okeechobee.

As the first step in federal involvement in the drainage of South Florida, the U.S. Army Corps of Engineers published their drainage and flood control plan in 1948. The plan recommended that the Kissimmee River be canalized and the Upper Chain of Lakes regulated at greatly reduced levels. The Corps designed, and in the 1960's, constructed a public works project that regulates levels in the Upper Chain by control structures and interconnecting canals. The system is designed to permit no more than a two-foot rise in the level of the Upper Chain of Lakes as the result of a 10-year storm. The Kissimmee River was replaced with a 30-foot-deep canal that straightened and shortened the river's length by some 38 miles. The ninety-mile-long serpentine river was displaced by a 52-mile-long canal (Fig. 22).

Control structures regulate the stage of the six individual impoundment pools along the canal. Canalization drained the floodplain and dropped adjacent ground-water levels. Upland drainage took place at a greatly accelerated rate after canalization.

Primary effects of Canal-38 and associated upland drainage can be generalized into the following categories: (1) the region's ability to produce high-quality water was greatly diminished, (2) the region's ability to store water was greatly diminished, (3) surface runoff of degraded water quality was greatly increased, (4) fish and wildlife habitat and populations were greatly diminished, and (5) land-use patterns underwent large-scale changes (Fig. 21).

Computer Model Studies of the Kissimmee River Valley

In September, 1973, the Central and Southern Florida Flood Control District funded a two-phase study entitled *Environmental Resources Management Studies in the Kiss-*

immee River Basin with the Department of Environmental Sciences, University of Florida. Principal investigators are Dr. James Heaney, Dr. Wayne Huber, Mr. Philip Bedient and Mr. Jerry Bowden.

Research Procedure

Objectives of this study are: (1) inventory all relevant environmental and hydrologic parameters for the Kissimmee Basin, (2) evolve a hydrologic computer model with which land use, drainage, vegetation patterns, nutrient loadings, and other ecological variables may be interrelated, and (3) undertake the development of environmental planning guidelines. Effects of management and land-use decisions on water distribution and other factors are being studied. The first phase report of this study was published on June 13, 1974.

Results and Discussions of Environmental Resources Management Studies in the Kissimmee River Basin Phase I*

The Kissimmee River Basin is undergoing transition from its natural state as a marsh and rangeland system to a new regime dominated by improved pasture, drainage ditches and canals. The area of lakes and swamps in the basin has declined from 37 percent of the total area in 1958 to 28 percent in 1972. In addition, approximately 40 percent of the native range that existed in 1958 has been converted to improved pasture.

Surface flow was not the primary way that rainfall from upland areas entered the Kissimmee River under natural conditions and prior to extensive drainage. The basin acted, in general, like a sponge which absorbed rainfall and released water slowly to the river and lakes primarily as subsurface flow, with lesser volumes arriving as surface flow through marshes and sloughs. The drainage density (defined as miles of surface drainage course, such as stream, slough, ditch, canal, etc., per square mile of land area) under natural conditions was about one mile of surface drainage course for each square mile of land area. Present drainage density in improved pasture has been increased by ditches to an average of over five miles of surface drainage course per square mile of area.

Surface flow has been greatly increased and subsurface flow greatly reduced as a result of upland drainage. Preliminary analysis indicates that as recently as 1958, most runoff into the Kissimmee River received significant soil and/or vegetative filtering, which kept water quality high. It appears that much less of the present runoff receives such treatment before entering receiving waters.

*This section was abstracted from Heaney, et al., 1974. *Environmental Resources Management Studies in the Kissimmee River Basin, Phase 1.* Department of Environmental Engineering Sciences, University of Florida, Gainesville, Florida.

Agricultural development with extensive upland drainage connecting to Canal-38 has resulted in: (1) increased runoff of surface water, (2) degraded water quality from waste loading,(3)depressed ground water levels, (4) increased need for irrigation water, and (5) decreased fish and wildlife populations. Upland drainage has resulted in a higher ratio of surface to subsurface flow and consequently has increased peak flow rates in drainage canals and the river.

Figure 23 shows the effect of lake and wetland drainage in decreasing the water-storage capability of the region. Decreases in the storage capability of the area also decreases the region's natural flood attenuation ability. The flood attenuation ability of the basin was 0.02 in 1958, with 37 percent of the total area in lakes and wetlands. By 1972, the flood attenuation factor was reduced to 0.04. If land-use projections for 2020 (Reynolds et al., 1973) occur and lake and wetlands decrease to 14 percent, the natural flood attenuation ability of the Kissimmee Valley will have largely disappeared.

Reconnaissance of the basin reveals much need for improvement in livestock management and drainage practices. Heavy grazing occurs in various areas and dairy farms generate large waste loads. Large quantities of non-point agricultural runoff enter surface waters without treatment by either soil percolation or vegetative filtration. Farm ditches carry runoff directly to secondary drainage canals that convey the degraded water directly to Canal-38 and thence to Lake Okeechobee.

In summation, public and private drainage systems have resulted in less wet-season water for carry-over to the dry-season. Runoff from upland and secondary drainage systems receives little purification and thus contains increasing quantities of nutrients and other pollutants.

Nutrient Uptake and Water Quality Models of the Kissimmee Floodplain

In August,1974, the Florida Division of State Planning contracted with Florida Coastal Engineers of Jacksonville, Florida, for a computer model study of the nutrient uptake ability of the Kissimmee floodplain marshes. Principal investigators are Dr. Bruce Taylor, Mr. Eric Olson and Mr. George Register.

Research Procedure

This study has the following objectives: (1) assess quantitatively the water quality benefits that would result from reflooding part or all of the Kissimmee River floodplain marshes, (2) relate water quality findings quantitatively to

marsh-flow characteristics to provide knowledge for design and evaluation of potential alternatives for reflooding the marsh, (3) evolve various structural and/or management alternatives for Canal-38 that will reflood various percentages of the drained marsh up to complete reflooding, (4) evaluate the structural and management alternatives developed, and (5) provide specific recommendations for implementation of a floodplain management plan that will increase nutrient uptake and improve water quality.

Objectives (1), (2), and (4) will be accomplished by simulation of two computer models. These models are being applied to a 107-acre section of the Kissimmee floodplain known as the Boney Marsh, an area that has many desirable physical and ecological characteristics which are conducive to the examination of various flow regimes under controlled conditions. The site had been selected by the Central and Southern Flood Control District for long-term study of marsh nutrient and water quality relationships. Both the Flood Control District and the Florida Game and Fresh Water Fish Commission have collected site specific data in the Boney Marsh. Subsequent study by the Flood Control District should provide field data for verification of the models and their predicted water velocity and residence times in the marsh.

Results and Discussion of the Nutrient Uptake and Water Quality Models of the Kissimmee Floodplain*

Development of the hydrodynamic model was completed in January, 1975. Work is presently focused on the water quality model. Preliminary design relationships between flow characteristics and water quality should be available in early April with final versions following later in the spring.

Considerable work has been accomplished regarding structural and management approaches to the reflooding of various portions of the floodplain. Approaches under consideration range from modified regulation schedules for the impoundment pools to a complete restoration of the Kissimmee River to precanalized conditions.

Cataloging and analysis of the physical characteristics of each Canal-38 structure and impoundment has resulted in the development of a preliminary plan which does not significantly alter present physical characteristics and which demonstrates graphically how the pools can be modified with minimum cost and effort.

This management alternative illustrated for Pool D of Canal-38 in Figure 24, consists of: (1) modified pool-regulation schedules, (2) modified auxiliary flow-control structures in the tie-back levees, and (3) some spoil bank modification. Modification of the other pools would include these features plus: (4) a mid-pool control structure, (5) auxiliary tie-back levees, and (6) dike modifications. The boundaries of active marsh under the existing regulation schedule of 21 feet MSL and the predicted boundaries that would result from increasing the pool regulation schedule to plus 23 feet MSL were analyzed. Marsh acreage in Pool D would be increased from 370 to a potential total of 2,310 acres.

*This section was abstracted from personal and written communications with Florida Coastal Engineers, 1974.

This plan would result in the reflooding of a total of approximately 14,190 acres of marsh. This would represent an increase of 160 percent over the approximately 8,840 acres of marsh that remain. Before canalization, the original marsh covered approximately 40,000 acres. The Central and Southern Florida Flood Control District presented a similar plan in 1972 which would reflood approximately 10,000 acres of marsh.

A rise in pool levels of 2 feet is used for illustrative purposes only, as final recommendations for regulation schedules will vary over the yearly hydroperiod and include optimum depths for nutrient uptake plus a draw-down period for oxidation of sediments, the release of annual plant seeds, and the removal of hyacinths. Auxiliary control structures in the tie-back levees at Structures 65D and 65E would promote circulatory flow through the marsh. The structures would control flow at near optimum rates for water quality and other considerations as determined by model simulation. Modifications to existing spoil banks would be necessary to promote flow and retain water on as large an area of marsh as possible.

The project will evaluate these two plans as well as the complete array of potential reflooding alternatives. A comprehensive cost-benefit approach will be used to consider all economic, ecological and water quality aspects to provide a rational basis for choice selection. Computer studies and analysis will supply quantitative estimates for the following germane questions: (1) what are the effects of nutrient loads delivered to Lake Okeechobee by Canal-38? (2) what feasible alternatives exist to reflood the marshes? (3) what are the water quality effects of each alternative? (4) what are the economic costs of each alternative? and (5) what are the other associated costs and benefits of each alternative?

Ecosystem Model Study of the Kissimmee River Floodplain Marsh

On September 30, 1972, the Florida Division of State Planning contracted with the Wetlands Center, University of Florida, for one element of a two-part cooperative effort with Florida Coastal Engineers (see preceding section). Principal investigators are Dr. Howard T. Odum and Mr. Larry Burns. The previous section discusses modeling of the physical transport and dispersal of water and materials to achieve detailed understanding of spatial variations within the floodplain. Results from that study will be used by the ecological model of the Wetlands Center. The Wetlands model will consider effects of flooding the marshes on vegetative changes, productivity, nutrient deposition, and fishery production.

Research Procedure

It has been demonstrated empirically that marshes remove dissolved nutrients and sediments as water flows through the marsh. Information on mechanisms, flows, and rates of nutrients cycling within the marsh is needed to quantitatively evaluate management alternatives. This knowledge will provide answers to questions such as: (1) do marshes act as net sinks for nutrients? (2) do marshes convert dissolved nutrient into organic forms that can be better assimilated by downstream ecosystem components and therefore, lessen stress on these downstream components? and (3) what management strategies will promote the long-term utilization of marshes for nutrient uptake and water quality?

The relative viability and vigor of marsh communities that would develop under each of the management alternatives will be modeled and assessed and related to nutrient uptake and wildlife values. Recommendations will be made regarding an optimum strategy for floodplain restoration that will recreate a managed marsh system to fulfill man's need for water quality enhancement and flood peak attenuation.

Results and Discussion of the Ecosystem Model Study of the Kissimmee River Floodplain Marsh

No results have become available yet for this study.

Water Quality Model of the Kissimmee River (Canal-38)

In September of 1974, the Florida Division of State Planning funded a water quality computer model study by Water Resources Engineers,Inc. of Austin, Texas. Principal investigators are Dr. Robert Brandes and Mr. Allen Johnson.

Research Procedure

Objectives of the study are: (1) identify and understand present sources and loadings of nutrient and other pollutants into Canal-38 that are subsequently delivered to Lake Okeechobee, (2) model actual and projected water quality characteristics including assimilative characteristics and transport characteristics of Canal-38, (3) model actual water quality loadings to Lake Okeechobee and predicted loadings under various alternative upland, floodplain, and channel management and structural modifications, and (4) evaluate and recommend alternatives for improved water quality.

The water quality constituents of primary concern include total phosphorus, total nitrogen, coliform bacteria, and organics. Data describing the concentrations and the quantities of water quality constituents in the several impoundments that comprise Canal-38 were obtained from the U.S. Geological Survey, the Florida Department of Pollution Control, and the Central and Southern Florida Flood Control District, for the period from August,1971 through August,1974.

Data from the Flood Control District for the period June, 1973 through August,1974 were used to analyze nutrient loads entering Canal-38 from local creeks, sloughs, and lagoons. Maximum, minimum, and average concentrations of total phosphorus and total nitrogen for each of the tributaries have been calculated.

Present modeling results are limited to information compiled from existing data. Once specific details are developed on various alternatives for reducing nutrient loads to Canal-38, the model will be modified and simulations undertaken to evaluate the alternatives quantitatively.

Results and Discussions of the Water Quality Model of The Kissimmee River (Canal-38)*

Data analysis shows that average total phosphorus concentrations in the northern reaches of Canal-38 are on the order of 0.03 mg/1. Between structures S-65C and Lake Okeechobee, concentrations increase to about 0.08 mg/1, indicating that tributary inflows contribute a significant amount of the total phosphorus entering Lake Okeechobee via Canal-38 (Fig.25 and Table 9).

Variations of average total nitrogen concentration are shown in Figure 26 and Table 10 . Concentrations on the order of 1.2 mg/1 are common, although maximum concentrations above 3.0 mg/1 have been observed. Average total nitrogen concentrations along the river do not exhibit significant increase due to tributary loadings, although concentrations show considerable variation between sampling periods.

Although the average concentrations of biological oxygen demand along Canal-38 are on the order of 2.0 mg/1, the total organic carbon data show a rapid increase from 12.5 mg/1 at Structure 65 to 18.0 mg/1 at the downstream end of the first pool near Structure 65A. Below Structure 65A, average total organic carbon concentrations do not vary significantly from a mean value of about 18 mg/1. Extreme variations in individual minimum and maximum measurements at each sampling station are apparent. It should be emphasized that these trends are based on only a few samples and may not be truly representative of long-term average conditions.

Inflows to the system from Lake Kissimmee and local tributaries have been identified. Stream flow data reported

*This section was abstracted from Water Resources Engineers, Inc., 1975. *Interim Report: Water Quality Model for C-38 Portion of Kissimmee River, Florida.* Austin, Texas.

by the U.S. Geological Survey for gauges at Structure 65 and 65E have been used to determine these external inflows in the model. Measured flows at Structure 65 have been used for the Lake Kissimmee release. Flow from each tributary drainage basin has been estimated using drainage area ratios to distribute the increased flow between Structure 65 and 65E because no flow data are available for any of the tributaries.

Wide variations in concentrations of nitrogen and phosphorus entering Canal-38 are apparent for practically all tributary inflows. Although total nitrogen concentrations are on the general order of those presented in Table 10 for Canal-38 itself, the total phosphorus concentrations in several of the tributaries are considerably higher than values given in Table 9 for Canal-38. Particularly high total phosphorus levels are indicated for Skeeter Creek, Armstrong Slough, Oak Creek, Chandler Slough, Yeats Marsh, Maple River, and Canal-41A.

The following conclusions can be drawn from preliminary research and simulations:

1. Nutrient data in Canal-38 are generally considered adequate for establishing present loadings to Lake Okeechobee from Canal-38. Organic and coliform bacteria data, however, are limited, and additional data surveys should be made to measure these quantities.

2. Additional constituent data should be collected for at least the major tributary inflows to Canal-38. Such information is needed to better quantify the loadings that are introduced through these inflows.

3. Average concentrations of total phosphorus and total nitrogen are considered high along the entire length of Canal-38, especially below Structure 65C where average concentrations approach those values normally associated with impounded waters susceptible to eutrophication. Maximum nutrient concentrations that have been measured in Canal-38 are well above concentrations considered necessary for sustained algae production. Total phosphorus concentrates are relatively constant above Structure 65C, but they exhibit a marked increase between Structure 65C and Lake Okeechobee. Total nitrogen levels are relatively constant throughout the entire canal length.

4. Available data for coliform bacteria indicate that present Canal-38 levels are safe for public drinking water supplies by Public Health Service Standards.

5. Organic substances in Canal-38 waters do not appear to be high for natural surface waters. Runoff from adjacent land carries some organic loads from cattle and dairy industries; however, identification of those specific tributaries where abatement practices should be considered is not yet feasible, but will be contained in the final report.

6. Based on assessment of all available water-quality data both for Canal-38 and tributary inflows, it appears that the most significant loadings to Canal-38 occur between Structure 65C and Lake Okeechobee.

7. Except for some minor adjustments, the water-quality model of Canal-38 is considered adequately verified for testing the effectiveness of various proposed alternatives for reducing nutrient loadings to Lake Okeechobee.

Study of Optimum Management Strategies for Cattle Production in the Kissimmee River Basin by EcoImpact, Inc.

Cattle ranching is by far the largest land use in the Kissimmee Basin. Cattle ranches in the basin vary in size from less than 100 acres to more than 50,000 acres, with herds ranging from fewer than 50 head to 8,000 or more. Blood lines vary from purebred herds to Florida scrub cows of unknown lineage. Carrying capacity and stocking rates differ between various grades of native range and improved pasture. Some native range supports a cow on 30 or more acres whereas better native range supports a cow on 2 or 3 acres. Intensively managed, improved pasture often carries a cow to the acre or less. Some less-productive improved pasture requires five or more acres per cow.

Productivity on Florida pasture is fairly low and much of the range has been chronically overstocked and is overgrazed. Calculations made by the U.S. Forest Service during analysis of range management problems in South Florida suggest that native range was stocked to 150 percent of actual carrying capacity (Rumell, 1956).

In 1958, there were 122,200 acres of improved pasture in the Kissimmee Basin. In 1972, there were 576,200 acres; an increase of 370 percent (Heaney et al., 1974). Annual application of 300 pounds of a 10-10-10 fertilizer per acre on improved pasture over about 60 percent of the basin appears to be near the present norm. Application rates and other factors vary widely while rapidly increasing fertilizer and other costs combined with low beef prices have produced a downward trend in application frequency and rate. Cattle extension specialists estimate that only 25 percent of the basin's improved pasture was fertilized in 1974.

Construction of Canal-38 drained the floodplain and lowered the water table. Extensive drainage of upland native range, and enlargement and channelization of tributary streams and sloughs took place after canalization. This has resulted in: (1) conversion of most of the floodplain to improved pasture, (2) increased conversion of upland native range to improved pasture, (3) rapid removal of rainfall during the summer wet season and increased drying during the winter dry season, (4) transformation of the drainage system from one of slow runoff and upland retention to rapid runoff and upland drainage, (5) reduced subsurface

base flow to Canal-38 from the shallow aquifer, and (6) increased nutrient loads in runoff.

In April, 1974, the Florida Division of State Planning funded EcoImpact, Inc. of Gainesville, Florida, to investigate available knowledge on the ecology of the Kissimmee River Valley range, pasture, and cattle, as well as grassland and marshland ecosystems and their use in sustaining livestock. Principal investigators were Dr. George Cornwell and Mr. Steve Gatewood.

Research Procedure

Available knowledge was to be surveyed and formulated for two hydrological regimes: (1) decanalization of Canal-38 with heightened water tables, a lengthened hydroperiod and more wetland and marsh range, and (2) continued canalization with a shortened hydroperiod, declining water tables, and more upland range and improved pasture.

Research data were gathered regarding: (1) effects of cattle ranching in the Kissimmee Basin on water quality, (2) primary productivity values for native and improved range, (3) cattle carrying capacities for marshland, native, and improved range, (4) methods for improving the quality of runoff from improved pasture, and (5) effects of decanalization on these factors.

Cattlemen, agricultural extension agents, university researchers and others were interviewed. Data and research information were correlated with interviews and field observations for analysis and synthesis. Before canalization, the floodplain marshes were used principally for winter grazing periods when upland range was drought or freeze-stressed. Canal-38 reduced total marsh area in the floodplain from 40,600 acres to 8,840 acres (Pruitt,1975).

Results and Discussion of the Study for Optimum Cattle Management in the Kissimmee River Basin*

Much of the Kissimmee floodplain has been converted from marsh that maintained itself and was available during periods when improved pasture was not productive, to improved pasture that needs extensive and costly management. Based on production figures for marshes and improved pastures, it is suspected that potential forage production from the natural floodplain marsh under proper management is very close to present floodplain production, which includes much improved pasture. A more precise estimate will be possible when aerial photography mapping of the floodplain vegetation is completed and appropriate cattle-carrying capacities for the floodplain in the pre-canalization period and at present have been determined.

*This section was abstracted from Cornwell, G.W. and Steve Gatewood, 1975. *An Analysis of Cattle Ranching in the Kissimmee River Basin.* EcoImpact, Inc., Gainesville, Florida.

The change from marsh to improved pasture took place abruptly in the floodplain during and after canalization which began in 1962 and was completed in 1971. Therefore, only short-term changes have expressed themselves so far; long-term effects on both cattle operations and the ecological support system are unknown.

Other research is evaluating the extent and consequences of upland drainage and subsequent conversion of large areas to improved pasture. Extensive drainage in connection with construction of Canal-38 has lowered regional ground water levels approximately 1.5 feet to several feet. It appears certain that a regime of upland retention, using weirs, tie-back dikes, etc. would provide for better water control and nutrient retention that could maintain optimum water tables and greatly improve the quality and reduce the quantity of runoff to Canal-38. Properly designed and operated upland retention systems would also retain sufficient water for maximum production of upland marshes for winter cattle forage.

It appears that the basin is overstocked with cattle. The number of cattle should be reduced to conform with the long-term carrying capacity of the area. This reduction would decrease both range degradation and the environmental impact of cattle ranching.

The Soil Conservation Service has recently concluded that under current conditions, Central Florida ranches would benefit by improving native range rather than continuing to convert native range to improved pasture. Although present market conditions may change, it appears certain that fertilizer and other costs of improved pasture will continue to rise. Ranchers who convert native range to improved pasture will find themselves in an economic squeeze because of rising maintenance costs, whereas ranchers with less improved pasture will have lower total operating costs. Apparently, the most stable and profitable ranching for the future is a combination of improved pasture and native range, including marshland forage. Interviews and analysis indicate a ratio of 25 percent improved pasture to 75 percent native range may be a preliminary design ratio.

This finding is compatible with the regional planning concept of optimum diversity of land use for a balance between systems needing high energy and systems that need only low energy management. If too much land is allocated to high energy, high yield systems, effective buffering by natural systems is precluded and resultant imbalances cause disruption of ecosystem benefits such as good water quality. If too much area remains in low yield systems, man misses the benefit of high yield systems. Proper planning and integration of the two are vital. High yield improved pastures, for instance, should be located so that runoff is filtered by natural systems before entering Canal-38. This arrangement would protect water quality, and in addition, nutrients transferred from improved pasture to the natural system would increase productivity in that system for cattle. Figure 27 shows a conceptual system of improved pasture and controlled marshes that intercept and utilize nutrient runoff.

Water quality data from Canal-38 shows a marked increase in total phosphorus going downstream from S-65C to Lake Okeechobee. Analysis by Heaney et al., (1974) indicates that area of improved pasture also increases going downstream, with large areas of improved pasture along the southern portion of Canal-38. Aerial photographs show the prominence of intensively ditched improved pasture in the lower basin.

Land owners should be responsible for the quantity and quality of runoff leaving their land. If high nutrient levels are present in runoff from improved pasture, ranchers should take advantage of natural purification processes by using controlled marshes for nutrient uptake. Present nutrient loads of Canal-38 and Lake Okeechobee should be trapped on the ranch land to grow marsh forage for supplemental cattle feed during freezes and drought. The Soil Conservation Service and other federal and state agencies should assist in the implementation of such systems.

Vegetative Community Mapping of the Kissimmee River Floodplain Before and After Canalization

In December, 1974, the Florida Division of State Planning began work to map the Kissimmee River floodplain. Objectives were: (1) quantify patterns and area of various marsh communities that occupied the floodplain prior to canalization, (2) quantify patterns and area of present marsh and improved pasture as well as upland vegetation that have invaded the floodplain due to canalization.

Results will provide baseline information necessary for understanding the natural floodplain ecosystem and for evaluating the various reflooding alternatives. Acreage of the various vegetative communities before and after canalization will be multiplied by the carrying capacity for the floodplain under both regimes. These acreage figures will also be used for quantitative evaluations of areas that should be reflooded.

Research Procedure

Natural and cultural habitats of the Kissimmee River Floodplain were outlined on acetate overlays of aerial photographs taken before, during and after the construction of Canal-38. The overlays were checked in the field to establish ground truth. Blueprint copies of each habitat were measured by an automatic area meter device to derive approximate acreages. Quantification of cattle carrying capacities of the various habitats is to be derived in conjunction with the associated study of the Kissimmee Basin cattle industry.

Results and Discussion of the Study of Vegetative Community Mapping of Kissimmee River Floodplain*

Construction of C-38 has produced profound and obvious effects on floodplain vegetation. Marsh occupied 78 percent of the precanalized floodplain. Since canalization, this marsh has been reduced by almost 70 percent. Remaining marsh is found only upstream from control structures and in small amounts in many small shallow depressions. Pasture was a small component of the precanalized floodplain and was confined to narrow zones between the marsh and adjacent uplands. Pasture has now increased to about 54 percent of the floodplain, 18 percent of which is improved pasture.

Small and sparse shrubby thickets have increased in area by a factor of almost four. Upland shrubs, which have almost no forage value for cattle, have to a significant degree invaded about 29 percent of the floodplain's unimproved pasture.

Approximately 8,680 acres (16.7 percent) of the floodplain marsh has been covered with spoil from the dredging of Canal-38. About 1,300 acres of spoil (2.5 percent of the floodplain, 15 percent of the spoil) is vegetated. Table 11 shows the area of various communities before and after canalization.

Results and Discussion by the Central and Southern Florida Flood Control District in their Lake Okeechobee-Kissimmee Basin Water Quality Study

Studies by the Central and Southern Florida Flood Control District of the water chemistry of the Kissimmee Basin indicate that "Intensive water quality sampling in Canal-38 initiated by the U.S. Geological Survey in 1971 under its cooperative program with the District, and expanded under the District's own program in Canal-38, in the tributaries to Canal-38, and in the lakes of the Upper Basin clearly indicates that the water leaving Lake Kissimmee and entering Canal-38 is of good quality." This reflects a more positive assessment of the quality of water entering Canal-38 from Lake Kissimmee than other studies of the project.

The District, in its March 20, 1975 project report (see Appendix B) concludes that:

1. Man's activities in the Upper Basin (upstream of S-65) at present do not contribute to whatever enrichment problems may be present in Lake Okeechobee.

*This section was abstracted from Pruitt, personal communications, 1975.

2. Man's activities in the Lower Basin upstream of Structure S-65C at present contribute little to whatever enrichment problems may be present in Lake Okeechobee.

3. At present the major contribution of enrichment to Lake Okeechobee in the form of phosphorus from the 2,320 square mile (excluding the Lake Istokpoga area) Kissimmee Basin derives from the 220 square mile area contributary to the S-65D and S-65E pools of Canal-38, and the 35 square mile area entering downstream of S-65E from the east; together a little more than 10 percent of the entire drainage area.

Results and Discussion by the Florida Department of Pollution Control in their Status Report on the Kissimmee River-Lake Okeechobee Special Project, April,1975 (see Appendix C)

1. There is a significant increase in nutrient loadings between Structure 65 of C-38 near Lake Kissimmee and Structure 65E near Lake Okeechobee, which add an estimated 4 million pounds of total nitrogen and 300,000 pounds of total phosphorus per year to surface waters from identifiable non-point sources.

2. Sediment study shows that highly organic sediments are deposited in the Canal-38 slough system during periods of low flow and that this load is flushed out into Canal-38 during the wet season causing an exceptionally high biochemical demand.

3. Data comparison of various slough systems along the Kissimmee River indicates the significance of agricultural practices on the magnitude of non-point sources of pollution. Runoff from improved pasture in the basin appears to contain far higher nutrient concentrations than comparable unimproved pasture.

4. In Shingle Creek, community diversity (a measure of environmental health and stability) increases with distance from sewage treatment plant outfalls, as would be expected, in direct correlation with chemical data. However, Blanket Bay Slough, where water quality is considerably poorer than Ice Cream Slough, still supports a more diverse fish fauna than the latter slough. This is an indication that channelization and its subsequent unnatural high-flow, low-flow regime may be detrimental to ecological communities, since recovery from channelization is far more complete in Blanket Bay Slough. Taylor Creek data are consistent with these findings also.

The Upper Kissimmee River Basin

The Upper Kissimmee River Basin comprises 881,000 acres of land and 130,400 acres of surface waters. Surface drainage in the basin begins in southern Orange County and flows into the Kissimmee Chain of Lakes. The watershed includes numerous streams, canals, and lakes including the major lakes of the Kissimmee Upper Chain. The same upland drainage modifications have occurred in the Upper Kissimmee Valley as in the Lower Kissimmee Valley. Figure 28 shows the configuration of the area under natural conditions and Figure 29 shows 1973 land use.

Sewage Inputs

The municipal sewage treatment plants of Orlando and other smaller plants and septic tanks in the basin produce 2.5 million pounds of nitrogen and 1.5 million pounds of phosphorus each year. Of this total, 1.8 million pounds of nitrogen and 1.1 million pounds of phosphorus are discharged by the municipal sewage treatment plants directly to surface waters of the Upper Chain of Lakes. Shingle Creek and Boggy Creek, both of which discharge into the Upper Chain of Lakes, receive 68 percent of the sewage effluent released to surface waters in the Upper Basin.

This constant and intense sewage loading has caused severe eutrophication of Lake Tohopekaliga and degraded water quality throughout the Kissimmee Upper Chain of Lakes. Recent research by the Florida Game and Fresh Water Fish Commission demonstrates that the cultural eutrophication of Lake Tohopekaliga results from: (1) discharge of treated and untreated human sewage, and (2) lake stabilization resulting from present flood control management.

An extensive drawdown was carried out in 1971 to approximate the historical low-water levels that prevailed under natural conditions prior to lake level control. The drawdown significantly increased the nutrient assimilative capacity of the lake and enhanced production of sports fish. Sewage loadings are of such magnitude, however, that even the increased assimilative capacity of the lake is being rapidly overwhelmed after the drawdown.

Preliminary analysis indicates that Lake Tohopekaliga and other downstream lakes of the Kissimmee Upper Chain of Lakes are now acting as sewage polishing ponds to treat large sewage loads. This is demonstrated by the fact that water leaving the Upper Chain is of greatly improved quality as compared with that in the northern sector of the Upper Chain.

The U.S. Environmental Protection Agency and the Florida Department of Pollution Control, in recognition of the present intolerable levels of sewage effluent entering the surface waters of the basin, have established a policy of allowing no additional sewage treatment plants that will discharge sewage to surface waters. In addition, existing dischargers of sewage effluent to surface waters must

proceed with planning and development of alternatives. Alternatives to surface discharge are: (1) land spreading of secondarily treated wastes, (2) deep well injection of secondarily treated wastes, and (3) advanced waste treatment with high-rate recharge. Since new or increased surface discharge will not be permitted, hopefully the no-discharge policy will result in increased funding priorities for correcting present excessive surface discharge of sewage effluent.

Advanced waste treatment is a proven but very expensive method for improving sewage effluent, and costs will undoubtedly continue to climb. At present, deep well injection is not a proven alternative as suitable tests have not been performed. The Southwest Orange County sewage treatment facility will, with Environmental Protection Agency funding, expand its facilities and begin testing a deep well injection program. Land spreading of sprayed effluent for irrigation purposes appears to be the optimum alternative for eliminating discharge into surface waters. Purchase of lands for spray irrigation is a large cost factor, however, and leases and cooperative agreements with farmers and other landowners should be investigated.

The urban areas should act to upgrade their effluents for some type of land disposal as there seems to be no other possibility for achieving significant reductions by other methods until the Orlando southwest deep well injection program becomes functional, should testing prove its feasibility, in late 1976 or early 1977. Further improvements beyond that date do not appear likely until the end of the decade, unless land spreading can be implemented.

The Florida Game and Fresh Water Fish Commission has requested that the Central and Southern Florida Flood Control District consider fluctuating schedules for the Upper Chain of Lakes so that both higher and lower lake levels may be achieved. After hearings to consider the wishes of the public, the Flood Control District has responded that only the suggested lower levels will be adopted. The District has given assurance, however, that if warranted, regulation schedules may be further modified in the future.

Upper Chain of Lakes Models

On October 23, 1974, Florida Department of Pollution Control funded the Wetlands Center, Universtiy of Florida, to apply to the Kissimmee Upper Chain of Lakes, the modeling techniques being developed for Lake Okeechobee. Principal investigators are Dr. H.T. Odum, Dr. Frank G. Nordlie, Maurie Sell, Wade Smith, Thomas Shapiro, and Darlene Grocki. Study design and models are similar to those outlined for Lake Okeechobee.

Research Procedure

The lake models simulate nutrient sources, pathways, sinks and other ecological relationships to determine the functional characteristics of the various lakes. The models will predict the assimilative capacity and trophic state responses to continued sewage inputs, drawdowns, and various regulation schedules. From the basic model, the following sub-models are being created for Lake Kissimmee: (1) a hydrologic model, (2) a nutrient model, and (3) a detailed fishery model. Once developed, these models will be adapted to Lakes Hatchineha-Cypress and Lake Tohopekaliga.

An associate model will include all individual lake models in a regional model to simulate economic flows and agricultural productivity as well as natural flows of energy and materials in the upper basin. This model will evaluate various alternative management schemes for the individual lakes, and will predict the effects of management alternatives on water quality entering Canal-38 for delivery to Lake Okeechobee.

Results and Discussion of the Upper Chain of Lakes Model*

Regulation of lakes for flood control has resulted in a decreased range of fluctuations from wet season highs to dry season lows. Compared with natural annual fluctuations, Lake Tohopekaliga has experienced a decrease from the former 29 percent fluctuation of total area under natural conditions to the present 11 percent fluctuation. Lake Hatchineha-Cypress fluctuation has been decreased from 100 percent to 65 percent. Other lakes in the basin have undergone similar reductions in percent of annual fluctuation to total area. This reduction in fluctuation has direct detrimental effects on fish and wildlife because large areas of productive rooted vegetation along shallow areas near shore become permanently reduced in area and vitality (Heaney et al., 1974). Wagener et al., (1974) has also demonstrated that stabilization of water levels decreased Lake Tohopekaliga's assimilative capacity, rendering it more vulnerable to eutrophy from sewage loading, and conversely, that drawdowns with oxidation of littoral-zone sediments temporarily rejuvenated Tohopekaliga.

The entire Kissimmee River Valley has been converted by extensive drainage from a subsurface drainage system, in which water percolated downward through the soil and entered wetlands as filtered and purified seepage flow from the shallow aquifer, to a regime characterized by increased surface drainage per square mile of area. The natural drainage density of less than one mile of surface drainage course per square mile of area has been changed to 12 miles of surface drainage per square mile of area in citrus areas and 5 in pasture areas. This trend is accompanied by significant increases in total drainage and irrigation, and conversion of natural lakes to reservoirs following the pattern of Lake Okeechobee. This change has created shifts

*This section was abstracted from Grocki , Darlene, *Basic Lake Models*, and Laurence Shapiro and Wade Smith, *Water and Phosphorus Budgets for the Upper Chain of Lakes*, and Smith, *General Lake Models, 1974* . In Odum, et al., 1974. *Water Quality Models for Understanding Potential Eutrophication in Lake Okeechobee, Florida.* Wetlands Center, University of Florida, Gainesville, Florida.

in recreational values and degraded fish and wildlife values (Heaney et al., 1974). These phenomena also lead to increasing degradation of water quality.

Analysis indicates that Lake Tohopekaliga and other lakes of the Kissimmee Upper Chain are presently acting as efficient nutrient sinks for current levels of urban and agricultural runoff and sewage. However, water leaving the Chain of Lakes and entering the Kissimmee River is, at present, of sufficiently low quality as to be of concern. Work is underway on a model of the upper and lower portions of West Lake Tohopekaliga to determine how long that lake is capable of operating as a sewage polishing pond under present loading rates.

The Agricultural Area

Figure 30 shows pre-development vegetative patterns in what is now the Everglades Agricultural Area. Drainage of the rich mucklands of the Everglades south of Lake Okeechobee began in the late 1880's when canals were dug from the lake to the sea. In the 1940's, Soil Conservation Service research demonstrated that much of the Everglades was not suited for agriculture because the muck depth in all but the area just south of Lake Okeechobee was too shallow for cultivation. By the time this determination was made, the Everglades and all South Florida were badly overdrained.

Extreme droughts in 1931 and 1945 resulted in greatly lowered groundwater levels over the entire region. When water levels dropped, salt water intruded into well fields threatening the water supply of Miami and other coastal cities. Salt water intrusion, raging fires that often burned the dried muck soils down to bedrock, and great losses of muck through oxidation were gross symptoms that the ecosystem was suffering chronic stress from overdrainage, general mismanagement and abuse (Parker, Gerald G. et al., 1955).

In June of 1947, preliminary to federal involvement in the drainage of South Florida, the U.S. Army Corps of Engineers held public hearings to present their water control plan. They proposed to surround the lake by levee and to drain by canal the approximately 1,200 square miles immediately south of Lake Okeechobee to create the Agricultural Area. They also proposed vast water conservation areas south of the Agricultural Area, more canals to drain Okeechobee, improvement of efficiency of canals already dug, and canalization of the Kissimmee River.

Everglades muck comprised the largest single body of organic soil in the world and the Agricultural Area originally comprised about 38 percent of all Everglades muck. Muck immediately south of the lake was originally as deep as 18 feet, becoming gradually shallower to the south so that at the southern end of the Agricultural Area the original muck depths were approximately 6 feet.

The Agricultural Area has been the site of intensive agriculture since drainage became successful in the 1930's. Sugar cane is the predominant crop with approximately 70 percent of the area devoted to sugar production. The remaining area is in vegetable and sod production. Figure 31 shows 1973 land use. When muck soils are drained for agriculture, the exposed soil undergoes microbial breakdown with resultant subsidence. A by-product of this process is the generation of nutrients as muck is broken down. Nutrients generated by muck subsidence may: (1) be held by the remaining muck, (2) enter the soil water, (3) be utilized by plants, and (4) be transported by water flows into the canals that criss-cross the Agricultural Area (Fig. 32).

During the wet season, when water control is necessary to keep crops from becoming inundated, the farm corporations pump water from their fields into Flood Control District canals. The Flood Control District pumps this nutrient-laden water north into Lake Okeechobee and south to the water conservation areas.

Model Study of the Agricultural Area

On September 30, 1974, the Division of State Planning funded the Wetlands Center, University of Florida, to study and model the Agricultural Area. Principal investigators are Dr. H.T. Odum and Mr. Thomas L. Morris.

Research Procedure

Objectives of study are: (1) define the internal activities of the area, (2) define how the area interacts with Lake Okeechobee and downstream components of the ecosystem, (3) identify management alternatives, (4) evaluate alternatives, (5) evolve a management plan that prevents backpumping of large amounts of nutrient-rich water into Lake Okeechobee, and (6) evaluate methods for establishing closed nutrient cycles within the area.

Work has been focused on the interactions of the Agricultural Area with Okeechobee and the three downstream water conservation areas. Future work and reports will deal with the internal structure of the area and its interactions in the South Florida economy. Included will be such questions as how does the practice of backpumping fare when evaluated in terms of total cost and benefit to society. Research will include cost accounting of environmental side effects such as water-quality degradation and muck depletion. Computer models will provide systematic understanding of critical factors.

An average rate of subsidence in Everglade muck of over one inch per year has been firmly established. Figure 33 dramatically illustrates the magnitude of muck loss in the Agricultural Area. The predrainage volume of muck soil

contained in the Agricultural Area was approximately 7.1 million acre-feet. The total volume of remaining muck is approximately 2.8 million acre-feet (Morris, Thomas L., 1975). Approximately sixty percent of the total muck has been lost to subsidence. As a result, water quality in the Agricultural Area is notably poor. Nutrient concentrations are high, and water backpumped to Lake Okeechobee is the poorest quality water that enters the lake.

If present subsidence continues, agricultural activity will be greatly curtailed by the year 2000 and eventually terminated. It appears, in view of the continuing efforts to establish "muck allowances", that farm corporations in the Agricultural Area expect this to occur. Some studies have indicated that as much as 150,000 to 200,000 acres of muck soils in the Water Conservation Areas are available for agriculture. These projections are extremely unrealistic due to both the shallow depth of those muck soils and the vital need to retain the water conservation areas for water storage and nutrient management. Water Conservation Areas 2 and 3, for example, are recharge areas for the Biscayne aquifer during the dry season, and agricultural activities in these areas would greatly increase the chances of polluting the Dade and Broward County water supply.

The initial stage of data gathering and model simulation necessary for understanding overall system characteristics and causal relationships has recently been completed. Information has been gathered from the extensive literature now existing on South Florida and from interviews with researchers, managers, and agencies. Computer simulation and model refinement are now being accomplished. Model and data refinement and evaluation will culminate in June, 1975, with functional models that will test systems behavior and evaluate management alternatives.

Results and Discussion of the Model Study of the Agricultural Area*

Water control provides the only successful means of preventing excessive muck subsidence. A significant retardation of subsidence with continued agriculture may be realized by modifying management to maintain higher water levels in the muck soils. Present water levels are often held lower than necessary for crop growth from fear that if heavy rainfall occurred, water could not be pumped off quickly enough to avoid crop damage. The cost in muck subsidence may be too high under this management strategy. The final report will address these questions in detail along with the possibility of utilizing water-tolerant crops for higher water levels and lessened subsidence.

There is a ratio between nutrient generation from soil subsidence and nutrients that are fixed and therefore remain in the soil. This ratio is yet to be quantified. The poor quality of water in the Agricultural Area indicates that there is a large net generation of nutrients caused by muck subsidence over the area.

*This section was abstracted from Morris, Thomas L. and H.T. Odum, 1975, *Progress Report of the Everglades Agricultural Area Backpumping Model.* Wetlands Center, University of Florida, Gainesville, Florida.

Preliminary calculations indicate the generation of possibly as much as 35 million metric tons of nitrogen per year and 85,500 metric tons of phosphorus per year from the yearly volume of muck subsidence in the Agricultural Area. Nutrient values expected from this volume of muck subsidence are not showing up in the area's surface or soil waters, however, which indicates that large scale immobilization or recoupling of nutrients is taking place in the remaining soil.

Background levels of nitrogen and phosphorus are very high in the Agricultural Area. Research by Gleason (1974) indicates that water quality in the Agricultural Area, however, has not grown significantly worse since the 1940's. As the absolute amount and percentage of organic material in the muck continues to decline due to subsidence, the ability of the diminishing soil to immobilize and hold increasing levels of nutrients also may decline. Should this phenomenon occur and the declining muck volume become nutrient-saturated, a rapid release of large nutrient loads to Lake Okeechobee and the Water Conservation Areas could occur. This could cause serious nutrient stress on the entire South Florida ecosystem, already stressed in many areas by nutrient overloads. Such stress could possibly initiate the switching of Lake Okeechobee to a hypereutrophic condition.

An average of 350,000 acre-feet of water is backpumped yearly from Lake Okeechobee to the Agricultural Area during the dry season. Preliminary calculations suggest that this process results in a net export of 1,361 metric tons of nitrogen and 106.4 metric tons of phosphorus from the Agricultural Area to Lake Okeehcobee each year. Discounting rainfall, the Agricultural Area in 1973-74 contributed 14 percent of the water that entered Lake Okeechobee, 11 percent of total phosphorus, and 38 percent of total nitrogen (Davis and Marshall, 1975).

Nutrient export southward from the Agricultural Area to the Conservation Areas is higher yet. Approximately 550,000 acre-feet of water, transporting 3,087 metric tons of nitrogen and 194 metric tons of phosphorus, is pumped into the Water Conservation Areas yearly.

It is clear that water backpumped from the Agricultural Area to Lake Okeechobee contributes a very significant nutrient load to the already eutrophic lake. Calculations utilizing Joyner's (1971) data for nutrient inputs into Lake Okeechobee by rainfall and all other inflows show that the Agricultural Area contributes 29 percent of the average yearly nutrient load of the lake. If rainfall inputs are discounted, the Agricultural Area contribution is 38 percent of that entering the lake.

The feasibility of retaining runoff within the Agricultural Area to close nutrient cycles and stop present detrimental nutrient loads to Lake Okeechobee is being studied. Recycling reservoirs have been constructed on the Lake Apopka muck farms, and preliminary results appear promising. These recycling ponds were constructed a year ago with a ratio of one acre of recycling pond to ten acres of farm land. Since that time, no agricultural runoff has been discharged directly into Lake Apopka.

Various aquatic plants are being researched to determine the best plant species to facilitate mineral uptake and sedimentation of nutrients within reservoirs. As recycling reservoirs would probably be deep to minimize required acreage, a floating or submerged aquatic plant would probably be most useful. The water hyacinth may well be the final choice, especially in light of its floating habit, high productivity, and very large consumption of nutrients.

The approximately 33,000 acres of state-owned lands in the Agricultural Area known as the "Holey Land" and that portion of the Rotenburg Tract that lies east of the Miami Canal, are being analyzed for possible use as a retention reservoir for water and nutrient management. In view of the critical ecosystem management problems facing South Florida, especially water and nutrient management, it is urged that state-owned lands in the Agricultural Area should not be committed for any purpose until their value for regional water and nutrient management is quantitatively determined. Management alternatives and cost-benefit analysis to determine optimum use of the Holey Land and other state-owned lands in the Agricultural Area from a regional perspective are being performed by this study. Public Land ownership in West Palm Beach County, is as follows: (1) Water Conservation Area 1; 134,000 acres, (2) Water Conservation Area 2; 133,290 acres, (3) Corbett Wildlife Management Area; 120,000 acres, (4) the Water Catchment Area; 12,160 acres, and (5) approximately 4 townships of state-owned lands within the Agricultural Area itself. Also, available for additional water retention are state-owned lands in Hendry County and Water Conservation Area 3, which consist of 638,670 acres.

Of the 88,994 acres of state-owned land within the Agricultural Area, 18,994.5 acres are leased to various agricultural interests, with most leases extending into the 1980's. This leaves the recently purchased Rotenburg Tract and the Holey Land as the only immediate possibilities for water retention. The Holey Land, located in the extreme southwestern corner of the Agricultural Area, is probably large enough to serve as on-site retention for the entire Agricultural Area. However, preliminary calculations indicate that the expense of pumping water from the far northern reaches of the area, plus the time required to pump large volumes of water that distance, may prohibit utilization of the Holey Land as the sole retention area.

The water conservation areas are also being examined to determine their capacity to handle nutrient-rich runoff. It has been demonstrated that marshes capture and tie up nutrients in sediments and plant tissue. Maximum nutrient assimilation levels are being sought that would utilize the natural filtering ability of the water conservation areas without switching them to a less desirable system.

The water conservation areas abut the southern and eastern boundaries of the Agricultural Area. Their combined area of 906,360 acres appears ample to receive large nutrient loads. Studies by Freiberger (1973), and Mottrow (1973) and preliminary calculations by this study, suggest the water conservation areas could handle increased nutrient loads.

Methods for maintaining water tables at higher levels in the water conservation areas, particularly the northern portions of Water Conservation Area 3, are being evaluated. Higher water tables would retard soil subsidence and fire, protect present ecosystem structure and function, and greatly increase wildlife habitat.

In summation, water pumped from the Agricultural Area to Lake Okeechobee adds significantly to eutrophic stress on the lake. Alternative methods are being sought and state-owned lands in the area are being evaluated as water and nutrient retention areas as are the water conservation areas.

Taylor Creek - Nubbins Slough Basin

Agriculture has always been the dominant land use in the Taylor Creek-Nubbins Slough Basin, and drainage and irrigation systems were installed on most farms by 1959. By that year, the 126,000 acre basin was crisscrossed with 248 miles of ditches. The upper portion of Taylor Creek was channelized by the U.S. Soil Conservation Service. The U.S. Army Corps of Engineers has since installed over 40 miles of drainage canals and control structures and canalized Taylor Creek from its mouth to State Highway 70 (Soil Conservation Service, Work Plan for Taylor Creek watershed, 1959). This was justified as for navigational purposes. When Okeechobee City was threatened with potential flood as a result of pasture drainage north of the city, the Corps constructed a control structure at Taylor Creek to divert part of the flood flow to Nubbins Slough (U.S. Soil Conservation Service, 1973).

Marsh and pasture drainage in the basin has allowed increases in the acreage of improved pasture, croplands (tomatoes and watermelons) and citrus. Figure 34 shows the configuration of the natural communities of the basin and Figure 35 shows land use in 1973. Accelerated urban development along the southeastern coast of Florida initiated a migration of dairy farms from coastal areas into the basin, and twenty-four dairies, maintaining a combined herd of 40,000 cattle, now operate in the Taylor Creek-Nubbins Slough Basin. Surface runoff from dairies requires use of treatment lagoons and use of runoff to irrigate pastures.

Previous investigations (Joyner, 1973 and 1974; Davis and Marshall, 1975; Odum, 1953) indicate that the Taylor Creek-Nubbins Slough Basin contributes high nutrient loads to Lake Okeechobee (1,196,184 pounds of nitrogen per year and 82,090 pounds of phosphorus per year, Joyner 1974). In 1973-74, the basin contributed 11 percent of Lake Okeechobee's total water, 43 percent of total phosphorus and nine percent of total nitrogen (Davis and Marshall, 1975). As most of the watershed is devoted to agriculture, it is certain that nonpoint agricultural sources are the main generators of organic pollution. The prime objectives of this study are to identify those sources and develop economically feasible control measures.

Study of Taylor Creek-Nubbins Slough Basin

The Department of Pollution Control began special analysis of the watershed at the inception of the project in September, 1973.

Research Procedure

Objectives of the study are: (1) determine the nutrient loadings generated by each type of land use, (2) identify and evaluate management alternatives, and (3) evolve a management plan that will significantly reduce nutrient loads. In the analysis of land use and nutrient loadings, five major factors are being considered: (1) land use by the acre, (2) hydrologic soil type, (3) precipitation, (4) runoff coefficients, and (5) nutrient loading factors by land use.

Results and Discussion of the Study of Taylor Creek-Nubbins Slough Basin*

Preliminary analysis indicates that cattle wastes are the major source of nutrients that enter Lake Okeechobee from the Taylor Creek-Nubbins Slough Basin. This is especially true for dairy areas. Samples taken from a ditch that drains improved dairy pastures show concentrations of total nitrogen and total phosphorus 13 and 5 times greater, respectively, than levels in samples collected from improved pastures containing beef cattle. However, calculated runoff potential and nutrient loadings from various land use types indicate that improved pastures in the basin generate 64 percent of the total nitrogen and 81 percent of the total phosphorus annually. The estimated 100,000 basin cattle (including dairy) contribute approximately 22,000,000 pounds of nitrogen and 5,500,000 pounds of phosphorus to the land annually. Although all of this animal waste does not enter surface waters, the percentage that does could be reduced significantly if proper waste management procedures were followed.

The animal waste disposal system used by most Florida dairies consists of cleaning cows in a paved wash area prior to milking. The wash area is then flushed with water, and the milk-parlor is flushed after each of the two daily milkings. Waste water is gathered in an anaerobic lagoon where biological processes result in some reduction in nutrient levels. Effluent from lagoons may then flow into holding ponds that are not designed for treatment and generally have a retention capacity of 7-10 days. Effluent from these holding ponds is then either pumped or gate-released into gravity-flow seepage irrigation systems. These systems distribute the effluent throughout adjacent pasture areas. A few dairies dispose of effluent with sprinkler irrigation systems. A multiple lagoon system is considered the best available strategy for dairy waste management. Such systems can be implemented quickly. Land applications of effluents should be made only during periods of low runoff potential--that is, when grass production is relatively high and precipitation rates are low.

*This section written by staff of the Florida Department of Pollution Control.

Alternative waste disposal methods are being examined. Smith et al., (1971) suggests the process of waste refeeding for dairy cows. White and Taiganides (1971) have researched the possibility of waste pyrolysis. With the present shortage of both energy and fertilizer, methane digestion may present the most feasible solution to the problem. Not only does this method produce valuable energy, but the remaining sludge contains high nutrient value and can be utilized as fertilizer. Numerous researchers including Fairbank (1974), Parker et al.,(1974), and Hill (1974) are investigating the feasibility of this procedure.

After dairy cows are milked, they are fed in concentrated areas and released to pastures where they contribute nutrients to the environment in the same manner as range cattle. Cattle in these pastures spend the greater part of hot days under trees or in water. These habits concentrate wastes, cause over-grazing, and develop erodible paths. Low cost methods are available to alleviate these problems, for example, the Environmental Protection Agency (1973) abatement measures.

High nutrient loads from the Taylor Creek-Nubbins Slough Basin will continue to be a major factor in the eutrophication of Lake Okeechobee unless corrective measures are taken. The project will develop a comprehensive management plan to reduce nutrient loads from Taylor Creek-Nubbins Slough Basin to Lake Okeechobee, as part of final reports due in October, 1975. Under consideration are: (1) implement effective waste management techniques for dairy wastes, (2) keep grazing cattle away from drainage ditches and the creek, (3) decrease pasture land runoff, (4) divert runoff into wetlands to effect treatment, (5) establish "buffer zones" around susceptible bodies of water, and (6) identify other necessary measures.

Fisheating Creek Basin

Fisheating Creek Basin contains about 295,000 acres of citrus land, cattle ranches, and dairy farms. The predominant land use is cattle ranches. Although this basin has not been as drastically altered as other Lake Okeechobee subdrainage basins, there has been much drainage to increase rangeland. Figure 36 shows the configuration of the basin before modification. Figure 37 shows the 1973 land use.

Study of Fisheating Creek Basin

The Department of Pollution Control undertook special analysis of the Fisheating Creek Basin at the inception of the project in July of 1973.

Research Procedure

Objectives and methods of the study are identical with those discussed in the previous section for the Taylor Creek-Nubbins Slough Basin. Joyner (1974) estimates nutrient flows from Fisheating Creek to Lake Okeechobee to be 1,458,982 pounds of nitrogen per year and 70,865 pounds of phosphorus per year. In 1973-74, Fisheating Creek delivered (discounting direct rainfall on the lake) eight percent of Lake Okeechobee's inflow water, five percent of total phosphorus and five percent of total nitrogen (Davis and Marshall, 1975). This loading is generated almost exclusively by agricultural runoff.

Results and Discussions of the Study of Fisheating Creek*

Ranchers have drained wetlands in the basin for many years by digging small ditches and by increasing the capacity of Fisheating Creek Channel. Through this process, much of Fisheating Creek has been artificially enlarged. Fisheating Creek, however, is the only remaining major tributary to Lake Okeechobee that is not regulated by water-control structures. In 1957, channelization was authorized for Fisheating Creek Marsh, a portion of the total watershed, under Public Law 566 of the Soil Conservation Service. This work included 9.6 miles of ditch construction and 13.5 miles of channel enlargement. Also 172 miles of open drains were installed to be maintained by the landowners in the area.

Drained land loses much of its natural water-storage ability, and irrigation becomes necessary. Table 12 shows irrigation by water source in the basin. Irrigation of improved pasture accounts for 73 percent of water-use in 1968 and 75 percent of the projected 1980 needs. The magnitude of irrigation of improved pasture is significant in terms of runoff from improved pasture and the quality of receiving waters.

*This Section written by staff of the Florida Department of Pollution Control.

Several workers have calculated nutrient budgets for Lake Okeechobee based upon measurement of flow rates and nutrient concentrations for each inflow and outflow. Analysis indicates that the two major contributors of nutrients to Fisheating Creek are improved pasture and unimproved pasture. Pasturelands account for 29 percent of the total area of the basin. They account, however, for 46 percent of the nitrogen loadings and 54 percent of the phosphorus loadings. Hence, the primary emphasis for water quality improvement in Fisheating Creek Watershed must must be toward lowering the contribution of nutrients from pasture lands.

Lake Istokpoga

The Lake Istokpoga Basin is connected to Lake Okeechobee by Canal-41A and the Indian Prairie Canals and to the Kissimmee River by the Istokpoga Creek Canal. Figure 38 shows natural vegetation patterns in the basin and Figure 39 shows 1973 land use. Total nutrient flows to Lake Okeechobee from the Istokpoga Basin are presently small; however, water quality leaving the basin has degraded significantly in the past several years. Results of the more intensive drainage and land use studies being conducted in the other drainage basins will be extrapolated to the Istokpoga Basin in order to derive a management plan that will increase water quality.

SECTION III

SYNTHESIS ECOSYSTEM STUDIES

Many aspects of the work discussed in this report are being assimilated and synthesized for overall regional understanding in the larger-scale studies outlined in this section.

Regional Model of the Lake Okeechobee System

On October 23, 1974, the Florida Department of Pollution Control funded the Wetlands Center of the University of Florida to conduct a computer model study of the Okeechobee Basin. Principal investigators are Dr. H.T. Odum, Thomas Fontaine and Mark Brown. The objective is to gain broad perspective of the workings of man and nature in the region so that difficult management decisions can be based upon comprehensive evaluations.

Research Procedure

Computer models are being developed at several scales to incorporate the following regional information: (1) flows of metabolic work by natural and managed upland and wetland systems, (2) energy imparted by climatic factors, and (3) energy flows of the economic and industrial systems.

Models influenced by hurricane occurrence, increased cost of fossil-fuel energy, and alternative management regimes will be simulated and evaluated. Alternative regimes undergoing simulation and evaluation are: (1) dechannelization of the Kissimmee River, (2) elevation of controlled water levels in Lake Okeechobee, (3) crop rotation in which certain percentages of agricultural mucklands south of Lake Okeechobee would be allowed to revert back to marsh to be later rotated back into crops, (4) purification of secondarily treated sewage in wetland ecosystems, (5) elevation of the regional water table by two feet, (6) fuel prices that would allow continued regional growth at near present rates, (7) effects of potential decreases in incoming tourist money, (8) effects of potential decreases in incoming federal and state money, and (9) effects of decreasing fossil-fuel energy on: (a) energy-intensive agriculture, (b) the State's ability to continue backpumping high volumes of water from adjacent areas into Lake Okeechobee and plans to backpump water to the water conservation areas, and (c) the State's ability to operate and maintain levees, locks and other structures.

*This section was abstracted from Odum, H.T., and T.D. Fontaine, 1974. *Energy and Economic Flows in Lake Okeechobee and its Basins,* and T.D. Fontaine and M. Brown, 1974. *Energy Evaluation of Alternatives for Water Management in South Florida.* Center for Wetlands, University of Florida, Gainesville, Florida.

Results and Discussion of Regional Models of Lake Okeechobee Ecosystem *

Preliminary analysis indicates several relevant relationships:

1. Presently, 3.7 percent of South Florida funds go out of the region for fuel purchase. These fuels contribute 35 percent of the region's total energy budget.

2. Tourist dollars presently constitute 33.3 percent of all money inflow to the region. Federal money contributes 24.3 percent, and cash for manufactured goods, 21.9 percent. Minor flows make up the other 20.5 percent.

3. The largest money outflows are: (a) 35.5 percent for purchase of goods, (b) 26.8 percent for federal taxes, and (c) 16 percent for goods purchased. Minor flows make up the other 21.7 percent.

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These figures indicate that South Florida has been purchasing fuels of a high energy value at low prices with money that comes mainly from tourism and the federal treasury (Fig. 40). Questions for further simulation include: (1) how will potential declines in tourist and federal money affect South Florida's economy? (2) how will increasing fuel prices affect the production and sale of goods manufactured in South Florida? and (3) if food and other costs continue to increase and income decreases, how will these factors affect population and health?

South Florida, to a great extent, has built an economy on external fuel supplies and money that, given present trends, may continue to decrease. This could call the economic vitality of the region into question. The natural systems of South Florida may continue to attract a large amount of tourist and federal money despite rising costs. The natural systems, acting to amplify money coming into the region, are vital to the South Florida economy and should be managed carefully.

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Hydrologic Analysis of the Lake Okeechobee Ecosystem

The outstanding physiographic feature of southeastern Florida is the shallow trough in which Lake Okeechobee and the Everglades form the dominant features. This trough is part of a vast wetland, which has as its headwaters the Kissimmee River, Fisheating Creek, Taylor Creek, and several sloughs to the north and east of the lake. The shallow basin from Lake Okeechobee southward is remarkable because, for its size, it is composed largely of wet prairies, marshes, and lakes with no relation to the ground water storage system in its headwaters (Brooks, 1974). The subtropical climate pulses the system annually with alternating wet and dry seasons.

To the north of Lake Okeechobee on the slightly elevated Okeechobee plain, the Kissimmee River Valley begins in the small sub-basins that drain to the Kissimmee Upper Chain of Lakes. The southward flow of wet season water from the northern portion of the watershed through Lake Okeechobee into the Everglades and southward to Biscayne Bay and the Gulf of Mexico was a prime force in the evolution of the South Florida ecosystem.

The natural hydrologic regime in South Florida has been completely metamorphized by drainage. The huge public-works primary drainage system enabled equally comprehensive upland drainage by private interests and small public works projects. In the 17 county South Florida area, there are presently about 3,900 square miles of wetlands remaining from an original total of approximately 6,814 square miles. Of the original wetlands, 2,946 square miles or 43.4 percent have been drained (Bayley, 1974). This magnitude of drainage has greatly modified natural flow patterns, surface storage, and ground-water table.

Water management programs for drainage and flood control appear to be affecting the productivity of natural systems and agricultural systems by: (1) shifting natural systems to new types, resulting in a reduction of overall productivity, (2) lessening the region's ability to store water in surface wetlands and shallow aquifers, (3) increasing surface runoff, degrading water quality, and increasing nutrient and pollution loads and eutrophy, and (4) altering the natural fire regimes as both frequency and resultant damage from fires is increased (Robertson, 1953).

Research Procedure

On December 2, 1974, the Florida Division of State Planning contracted with Mr. William Hurst and Mr. Jerry Kubal of the Alachua County Pollution Control Office to study the hydrology of the Okeechobee Basin. Objectives of study are: (1) analyze the hydrologic performance of the basin under pre-development conditions, (2) analyze and quantify the hydraulic characteristics and performance of the flood control system in the basin, (3) analyze and quantify ground and surface water levels in the Kissimmee River and Taylor Creek-Nubbins Slough Basins before and after canalization, (4) evolve comprehensive recommendations for modification and management of the system for optimum water quality and water quantity, (5) assist in evaluating the hydraulic aspects of work and reports by the other project studies, and (6) prepare a written report detailing these matters.

The research procedure consists of (1) field reconnaissance supplemented by study of topographic maps and aerial photos, (2) a literature search of previous investigations, (3) a review of hydrologic work associated with the project, (4) use of all currently available hydrologic data, and (5) compilation and organization of all information into a comprehensive report on the hydrology of the Okeechobee Basin.

Results and Discussion of Hydrologic Analysis of the Lake Okeechobee Ecosystem

Because this study is presently emerging from the data-gathering stage, conclusions are not yet available.

Hydrologic Modeling of the Lake Okeechobee Ecosystem

As part of the overall study of the hydrology of South Florida, use is being made of analog computer models being developed by the Wetlands Center of the University of Florida.

Research Procedure

A hydrologic model has been evolved and simulated for Lake Okeechobee. This and a companion model dealing with the hydrologic flows of the entire region will be utilized. An overall water budget and recommendations for regional hydrologic management will be evolved.

Results and Discussion of the Hydrologic Modeling of the Lake Okeechobee Ecosystem

No conclusions will be available until model simulations are completed.

Economic Cost-Benefit Evaluation of the Present System and Proposed Management Alternatives

Many project studies are involved in evaluating aspects of economic and environmental cost-benefit ratios. There is need for an overall effort to work in conjunction with the Regional Model of the Lake Okeechobee Ecosystem by the Wetlands Center of the University of Florida to correlate and synthesize the various economic and environmental cost-benefit studies into a unified and comprehensive package. Once simulations are complete, it will be necessary to evolve new policies that will facilitate management implementation. These services will be provided to the Project by contract with Dr. Paul Roberts, Resource Economist.

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Relationship of Lake Okeechobee to Downstream Areas

As discussed in Section II, Lake Okeechobee is vital to downstream areas of South Florida. Figure 2 shows canals leading from Okeechobee and downstream areas. Various project studies are investigating effects of management alternatives on downstream areas.

The St. Lucie Canal discharges an average of about 940,000 acre-feet of water per year into the St. Lucie estuary at Stuart. Changes in both the amount and arrival time of freshwater and nutrients delivered to the estuary since the canal was completed in 1924 have severely stressed the St. Lucie estuary. The ecological conditions in the estuary are severely altered by fresh water discharged from Lake Okeechobee during the wet season, causing destruction of estuarine organisms. Grass beds which are nursery and feeding grounds for marine life have been smothered by organic silt from the canal, and the substrate altered to such an extent that grass beds are presently not capable for recolonizing much of the area.

The Caloosahatchee Canal delivers an average of 740,000 acre-feet per year to the estuary at Fort Myers, which has not been damaged as much as the St. Lucie estuary.

The Hillsboro, North New River, and Miami Canals deliver Lake Okeechobee water south to: (1) the Agricultural Area, (2) Water Conservation Areas 2 and 3 (3) the Biscayne aquifer, (4) Everglades National Park, (5) Biscayne Bay, and (6) Florida Bay. Water for irrigation is discharged by these canals from Lake Okeechobee into the Agricultural Area during the dry season and backpumped from them into Okeechobee during the wet season.

The three water conservation areas, consisting of 1,345 square miles surrounded by levees, are vital to water management in South Florida, although shallow, large volumes of water are temporarily stored in them. During times of intense rainfall, water is pumped to the water conservation areas from urban areas along the Atlantic Coastal Ridge. This ability to store water in the water conservation areas reduces floodpeak water levels in the urban areas and in Lake Okeechobee. During dry periods, seepage through levees and water released from the water conservation areas sustain higher levels of water in areas near the coast for periods longer than could be maintained after the Everglades were drained but before the water conservation areas were constructed (et al., 1972).

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During drought, Lake Okeechobee water is vital to the viability of Everglades National Park. Scheduled release of water to the Park is now regulated by law and is on the order of 260,000 acre-feet per year. In prolonged drought periods, the Park's water comes from the lake. Water from Lake Okeechobee is becoming increasingly important to Everglades National Park and the lower east coast. Presently, Lake Okeechobee water is needed primarily during prolonged drought, but in the future it may be needed on an annual basis.

Drainage Density Mapping of Lake Okeechobee Drainage Basin

Research in the Kissimmee River Valley by the Department of Environmental Engineering Sciences for the Central and Southern Florida Flood Control District, has derived an extremely valuable "drainage density" relationship. Drainage density, defined as the miles of surface drainage course per square mile of area, bears certain relationships to both the resident time and water quality of runoff. The Division of State Planning has recently funded the Department of Environmental Engineering Sciences to perform drainage density mapping for all Lake Okeechobee drainage basins except the Kissimmee River Valley which has been mapped under the Flood Control District contract.

SECTION IV

LEGAL AND ADMINISTRATIVE ASPECTS OF MANAGING LAKE OKEECHOBEE FOR WATER QUALITY

On June 31, 1974, the Division of State Planning contracted with Attorney Barry Lessinger to research existing governmental bodies within the basin and to analyze the scope and effect of the various jurisdictions. An analysis of management practices was made to determine what is enabled by existing legislation and what is actually being implemented.

Water resources within the basin are utilized for a variety of purposes. While agriculture and urban uses are primary, other aspects such as navigation and recreation are important and must be considered. Each user has a governmental body at the federal, state, or local level to regulate its use. A review of these entities was made in order that overlap and omission of regulations might be identified.

Research Procedure

The study reviewed the impact of various jurisdictions and practices on water and environmental quality. This perspective has been applied to existing management programs, including federal and state projects, and special districts. Literature review of recent management efforts and research into the legal ramifications of restoration of the Kissimmee Floodplain have been completed. Assistance in the coordination and review of the project's technical recommendations and their incorporation into the existing legal and administrative framework are also objectives. Two reports have been drafted entitled: *Jurisdiction Everywhere, Responsibility Nowhere,* and *The Legal Ramifications of Restoration of the Kissimmee Floodplain.*

Results and Discussion of the Legal and Administrative Aspects of Managing Lake Okeechobee for Water Quality*

Present state management jurisdictions in the basin arose from a series of legislative actions which were in response to specific management problems. It was, in effect, decision-making by crisis. The Central and Southern Florida Flood Control District, for example, was created in 1949 to replace earlier, less powerful, drainage districts after the 1947 flood made it apparent that drainage and flood control objectives had not yet been achieved. In the same manner, too frequently state agency activities have been problem or crisis-oriented. There has not been a comprehensive resource management program of any kind in the basin but only programs to control or develop narrow, often single-purpose, objectives. These programs are often in direct conflict in objectives and management approach. All too often, management history of the basin has been oriented towards crisis management, or management to assist special interest groups. Comprehensive management to encourage and develop sound resource protection and maximize the economic and ecological health of the region would be much more in the public interest.

Among the reasons for present affairs has been a lack of resource management knowledge and incentive for progressive change. The major structural defect is the fragmented and conflicting jurisdictions of local, state, and regional entities which have been established without sufficient resource management considerations. For example, analysis of the boundaries of the Regional Planning Councils, the Soil and Water Conservation Districts, and the Drainage Districts of the basin show that nowhere are the boundaries of these agencies coterminus. For many reasons relating to the extreme structural and functional integration of the South Florida regional ecosystem, it is virtually impossible to create a unified and effective management program within this melange of overlapping jurisdictional boundaries.

To properly manage the basin, it is necessary to create a management structure that: (1) encompasses the entire regional ecosystem, (2) is subdivided along functional boundaries such as subwatershed boundaries, (3) is unified to enable long-term optimum management for overall economic and ecological health and stability, and (4) is flexible and responsive enough to develop and implement a comprehensive scientific management plan that will be constantly updated and modified according to the feedback responses of the regional ecosystem and changing societal problems.

Existing state management programs are often severely limited. These limitations can occur through exemptions written into the legislation, exemptions and confusion in the rules adopted by agencies, and mis-management and non-enforcement in the administration of legislative programs.

The South Florida regional ecosystem has been managed since 1948 by the Central and Southern Florida Flood Control Project. Carter (1975) discusses some of the successes and problems of the Flood Control Project. Successes include: (1) eliminating of the threat of major floods along the lower east coast, (2) enabling the use of the Agricultural Area for farming, (3) reducing by approximately 20 percent of the loss of freshwater from the Everglades to the Atlantic caused by prior overdrainage, (4) lessening of salt water intrusion into the Biscayne aquifer, and (5) making the Everglades accessible to the general public. Problems include: (1) equitable cost-sharing arrangements that would encourage better use and conservation of land and water resources, (2) the need to give higher priority to storage and delivery of water to meet demands and needs already foreseen, (3) policies to keep land reclamation for agriculture and urban expansion from increasing water demands beyond the project's ability to increase water supplies, and (4) overexpansion of development in a region of limited tolerance for development.

*This section written by Mr. Barry Lessinger.

The 1972 Florida Water Resources Act provides the key to successful water management in the basin. It established the potential for South Florida to be managed effectively to optimize water quality, water quantity, ecosystem health, and economic vitality.

The ultimate fruition of the act will be a water plan which will consist of water quality classifications of stream courses and a water use plan. Indications are that the earliest date that the water-use plan can be expected under this framework is June 30, 1980. However, the Special Project will present a land-and-water-management-plan for the Lake Okeechobee drainage basins in the fall of 1975.

Reflooding of the Kissimmee Marshes and the Taking Question

Should ultimate management action entail reflooding of part or all of the floodplain marshes of the Kissimmee River, the question arises as to whether compensation has to be paid landowners. In general, the answer is no, if inundation is seasonal as under the natural precanalized regime. This is, of course, a very complex problem and the report recently completed as part of this project, *The Legal Ramifications of Restoration of the Kissimmee River Floodplain,* should be consulted.

SECTION V

PRELIMINARY CONCLUSIONS AND FINDINGS OF THE PROJECT TO PREVENT THE EUTROPHICATION OF LAKE OKEECHOBEE FOR OPTIMUM MANAGEMENT OF SOUTH FLORIDA

Ecological research on the South Florida regional ecosystem has now progressed to the point where overall understanding of the nature and function of the area is well defined. This understanding forms the framework within which man must manage the region if he is to preserve the fragile balance that makes South Florida such a unique region. The knowledge to manage the basin for optimum water quality, water quantity, and economic and ecological health is now emerging.

Florida lies in the latitudinal belt of the great deserts of the world. The sub-tropical climatic regime that prevails is characterized by a summer wet season from May through October and a winter dry season. Within this regime, there are often wet years where flooding occurs and dry years with severe drought. In most places, this type climate results in the existence of "tropical savannah" landscape; sweeping plains characterized by a long parched dry season during which the arid conditions make life very difficult.

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South Florida did not develop a tropical savannah ecosystem, however, due to a very unique set of conditions. Instead, the South Florida ecosystem was characterized by large areas of many types of wetlands whose organic soils acted collectively as a huge sponge to absorb and conserve wet seasons rains. These wetlands and their water-absorbing soils made water available during the yearly dry season as well as during scorching drought that occurred under natural conditions about one year out of six (Parker, Gerald G., 1974). The natural ecosystem literally developed the ability to sustain a highly diverse and productive aquatic and upland ecosystem where, but for the water conserving mechanisms of that ecosystem, an arid and harsh tropical savannah would exist. The importance to man of this water storage ability, developed over thousands of years by the living components of the ecosystem, cannot be overestimated (Carter et al., 1973).

The apparent superabundance of water in South Florida is an illusion engendered by the capability of the living ecosystem to store wet season water for later uses, (Carter et al., 1973). The ecosystem evolved these unique and invaluable methods of storing water because the environmental condition in South Florida over the last several thousand years was such that the ability to store water was and is the most valuable biological characteristic. Our ancestors, from the moment they set foot in South Florida, began a process of destroying the water-conserving mechanisms of the ecosystem by drainage and destruction of wetlands. This de-watering has brought about drastic changes in environmental condition and has degraded the surface waters of the region, including Lake Okeechobee.

The South Florida ecosystem is presently under a high degree of stress as a result of man's disordering of the system's evolved patterns of coping with the often harsh climatic conditions imposed upon it. The ability of the region to conserve wet season water for use during the dry season has been greatly disordered and diminished by drainage and destruction of wetlands. There are now approximately 1500 miles of primary drainage canals in South Florida, constructed and maintained by public works money. Connecting to this system are untold thousands of miles of private canals and ditches. In addition, in the 17 county South Florida area, there are presently only 3,900 square miles of wetlands remaining from an original total of approximately 6,814 square miles. Of the original wetlands in the basin, 2,946 square miles or 43.4 percent have been destroyed through drainage (Bayley, Suzanne, 1975). This magnitude of drainage and destruction of wetlands has greatly modified natural flow patterns, surface storage, and ground water storage. These trends, in addition, have greatly reduced the region's ability to assimilate nutrients so that as urban and agricultural development greatly increase nutrient loads, the ability of the area's aquatic systems to absorb nutrients has been greatly diminished. Nutrient stress and eutrophication are the obvious result.

Throughout the region there are clear and unmistakable signs that the ecosystem is switching to some as yet undetermined pattern--quite possibly some form of dry savannah. Long parched dry seasons with acute water shortages and uncontrollable wild fires and other stress have been experienced in South Florida to a degree that never occurred under natural conditions. Added to this is the corollary stress of eutrophication on Lake Okeechobee and the Kissimmee Upper Chain of Lakes. Fortunately, for man and nature in South Florida, these catastrophic trends appear to be reversable, provided effective management for optimum water storage and quality is implemented in the very near future.

The report cover map shows the optimum natural vegetation pattern that evolved to best accommodate life in South Florida under the harsh climatic regime that prevailed. If man is to continue to live in this very unique and beautiful but fragile region, he must quickly evolve new patterns and strategies that restore the system's ability to optimize water storage in ways that support life and preserve water quality. This goal is obtainable. It can be achieved within a decade, provided the necessary commitments are made and the fragmented management approach that presently prevails is revamped into an effective, well-directed, and purposeful program to effect real changes rapidly.

If the present switching of the South Florida regional ecosystem to savannah or other more arid conditions is not retarded, there will result a loss of productivity and fresh water for man. Man can live in South Florida only by understanding and protecting the vital functions of the natural ecosystem and integrating himself into it in ways that do not exceed its capability to absorb resulting stress.

Tentative Findings of This Project

There is agreement among all project participants that nutrient enrichment of Lake Okeechobee is a very real problem that must be dealt with through a comprehensive and thorough management scheme for the entire basin. All agree that the major problem areas of nutrient enrichment include:

1. *Taylor Creek-Nubbins Slough Basin* where nutrient loading, principally phosphorus, is disproportionally high;
2. *Agricultural Area* south of Lake Okeechobee, where backpumping contributes a high volume of nitrogen; and
3. *Lower Kissimmee Valley* (downstream of Structure 65C) where high phosphorus loading occurs.

All preliminary indications from computer simulation studies of Lake Okeechobee, indicate that it is a moderately eutrophic lake, best classed as culturally eutrophic. Conclusions of the Flood Control District indicate that the water chemistry of the lake has not basically changed in a five-year study period; however, other studies indicate that tremendous nutrient increases have been realized in other "compartments" of the lake's ecosystem (i.e., vegetation, sediments, etc.). Expectations are that by the end of the project, sufficient hard data will exist to pinpoint the eutrophic condition of the lake.

There remains some debate, principally due to the incompleteness of current studies, as to the problems manifested in the Upper Chain of Lakes and in Canal-38 (Kissimmee River) itself. There is no doubt that the Upper Chain, at the present time, "filters and upgrades" poor quality water from the area by the time they are discharged into Canal-38. However, the exact degree of potential danger which that situation manifests cannot be determined until all studies are completed.

While various management strategies have emerged during the course of the study, there is consensus among project participants that an overall ecosystem management strategy would be the most effective in providing long-range solutions to basin problems. The project participants feel that during the final phase, careful and critical attention should be given to analysis and review of data and computer modeling to evaluate management alternatives. The project will solicit public input from affected areas to insure the development of a cooperative design for a comprehensive management plan.

Tentative Management Conclusions

The general conclusions outlined here are designed, as much as present knowledge permits, to point out general directions for ecosystem regeneration and optimum integration of man and nature in South Florida. These conclusions are necessarily general, because the project is just now entering that phase of study where management alternatives are being evaluated quantitatively in a process that will lead to specific and detailed recommendations in the final reports in October, 1975. The balance of the project will be devoted to producing and refining the information and perspective necessary to evolve detailed management, implementation, monitoring, enforcement, research, and other related activities to prevent the further cultural eutrophication of Lake Okeechobee and better manage the regional ecosystem.

The key to optimum water quality and water quantity in South Florida is hydrologic management to optimize water storage, conservation, and wise use. *The overall strategy for maximizing survival in South Florida should be to hold rainwater as near the place it falls as possible.* Included in this general strategy are trade-off evaluations for irrigation, flood control, domestic water supply, delivery of needed fresh water to estuarine systems and Everglades National Park, and other vital water needs of man and nature.

The type of water-storage is critical. When water is stored in natural wetlands and the shallow aquifer, it is available for man and nature in a form that is not highly susceptible to degradation. Natural lakes, rivers, and streams normally have good water quality because they have a high biological assimilative capacity to absorb nutrient inputs. Reservoirs and canals are less efficient nutrient assimilators and are therefore more susceptible to pollution and eutrophication. In addition to being ill suited for water storage, they tend to flood downstream areas and greatly diminish the entire ecosystem's ability to store water for the dry season.

In the sub-tropical climate of South Florida which has annual wet and dry seasons and periodic drought, the survival strategy must be water conservation. Under natural conditions, South Florida utilized wetlands and their organic soil to store water for the annual dry season. This tried and proven strategy is the only sure pattern for maintenance of adequate fresh water supply and other needs of man and nature in South Florida.

The dilemma involves precise design and performance criteria such as the ratio of wetland to various other land uses, methods for re-establishment of wetlands, optimum management of wetlands for high productivity, water quality, and water quantity, and a host of related design and operations management questions. These questions will be discussed fully in the project's final reports.

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Illustrations

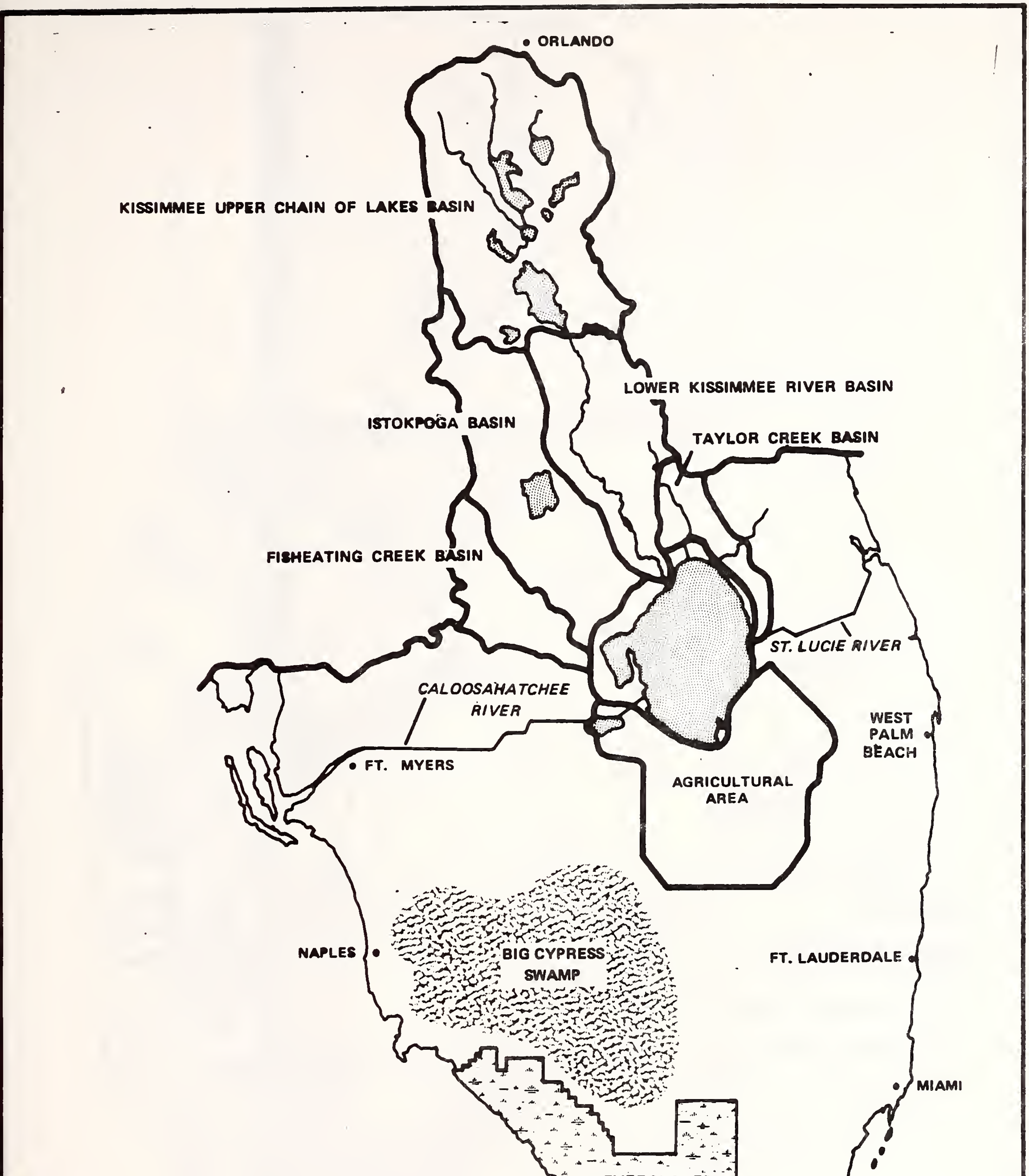

ORLANDO
KISSIMMEE UPPER CHAIN OF LAKES BASIN
LOWER KISSIMMEE RIVER BASIN
ISTOKPOGA BASIN
TAYLOR CREEK BASIN
FISHEATING CREEK BASIN
ST. LUCIE RIVER
CALOOSAHATCHEE RIVER
WEST PALM BEACH
FT. MYERS
AGRICULTURAL AREA
NAPLES
BIG CYPRESS SWAMP
FT. LAUDERDALE
MIAMI
EVERGLADES NATIONAL PARK
SOUTH FLORIDA REGIONAL ECOSYSTEM SHOWING THE OKEECHOBEE DRAINAGE BASIN

FIGURE 1

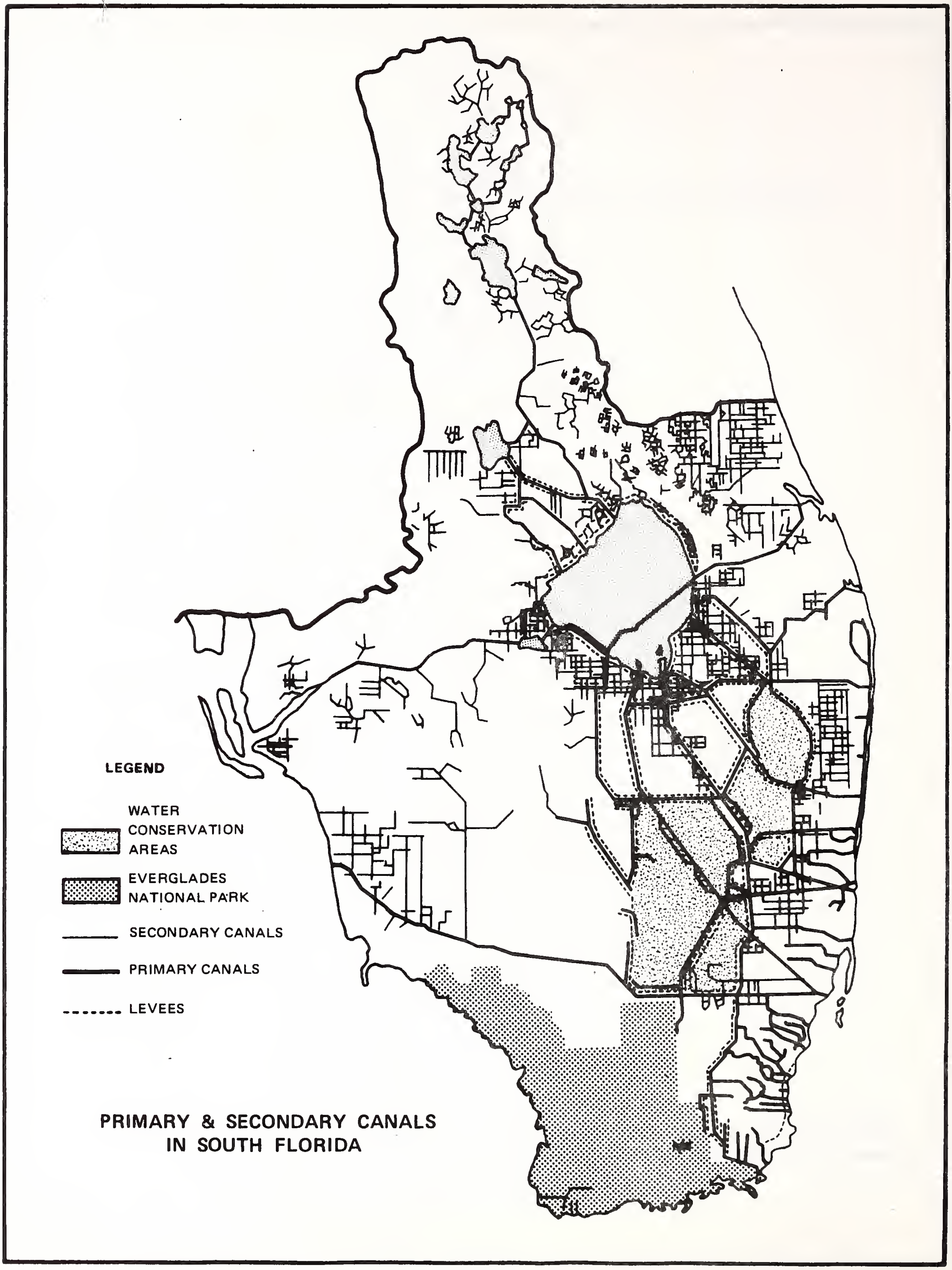
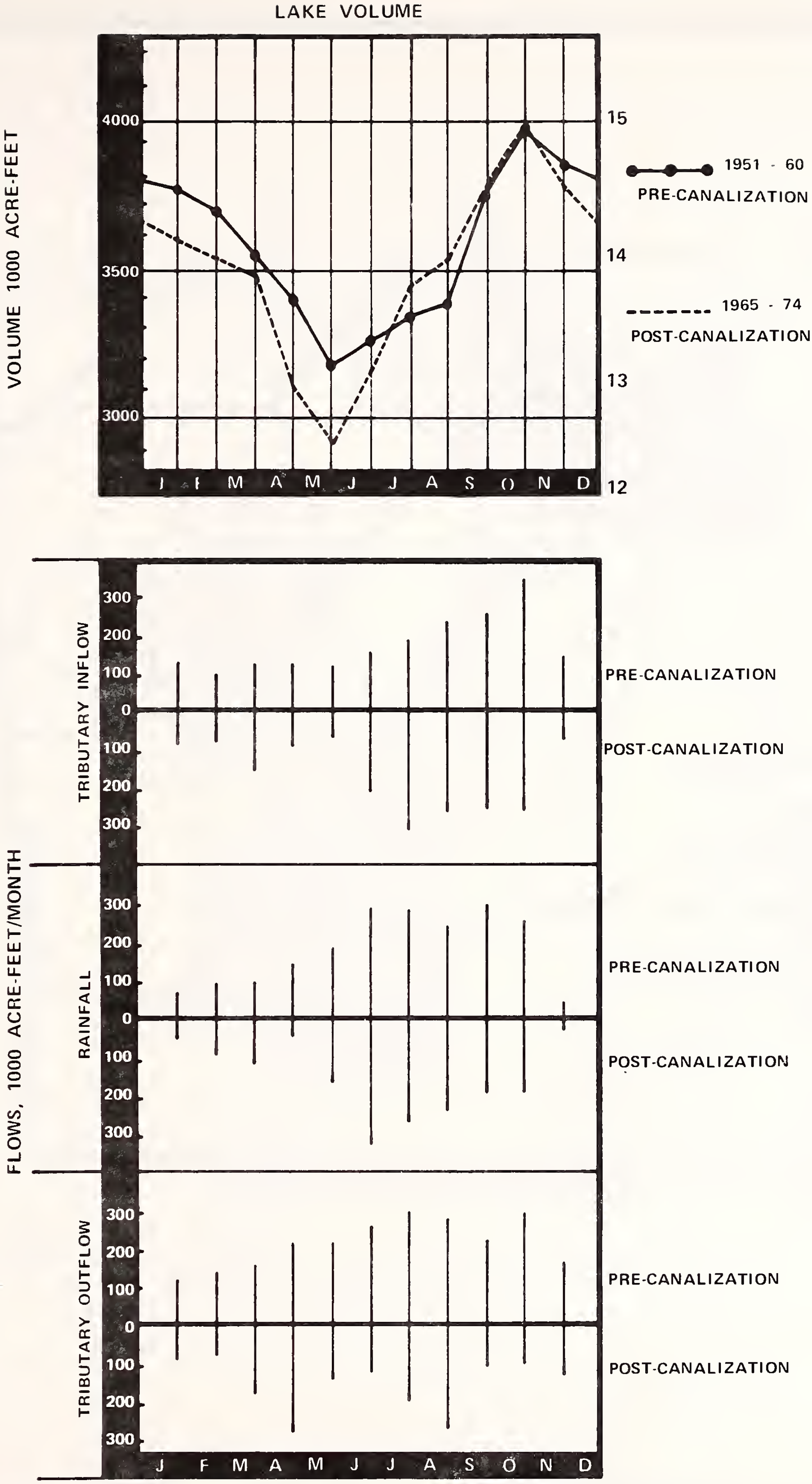
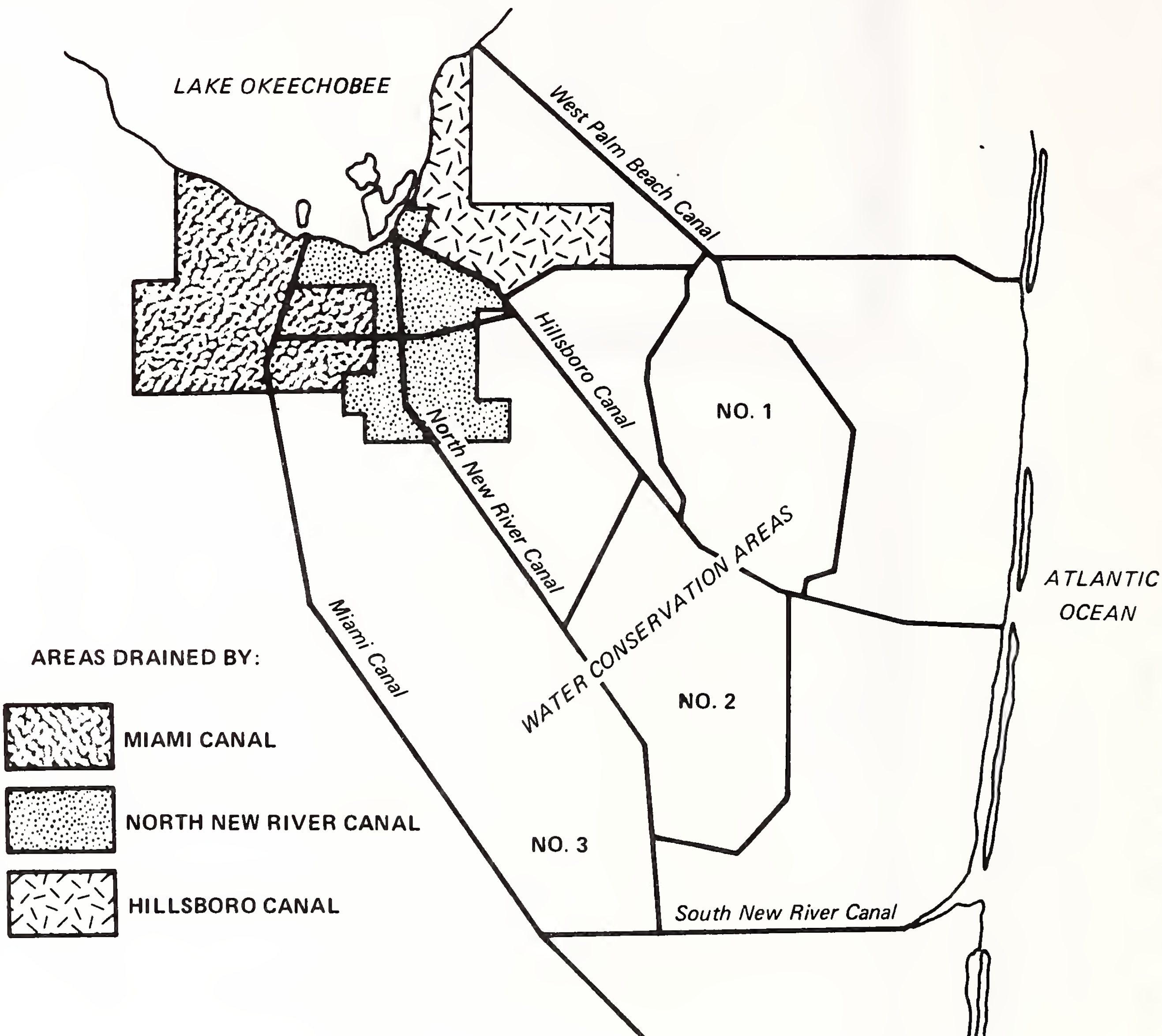

LEGEND
WATER CONSERVATION AREAS
EVERGLADES NATIONAL PARK
SECONDARY CANALS
PRIMARY CANALS
LEVEES
PRIMARY & SECONDARY CANALS
IN SOUTH FLORIDA

FIGURE 2



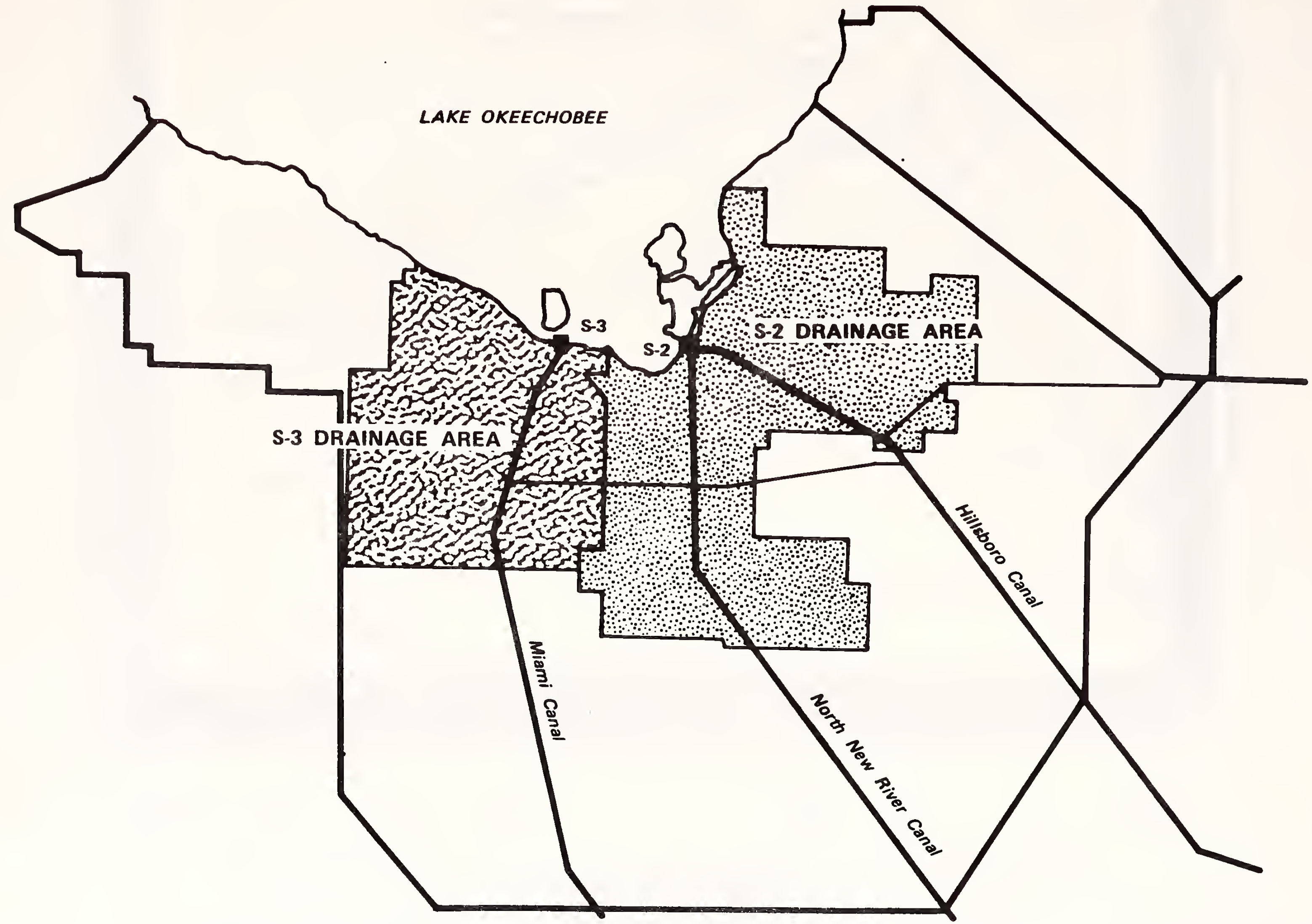
HYDROLOGY FEATURES OF LAKE OKEECHOBEE BEFORE AND AFTER CHANNELIZATION OF THE KISSIMMEE RIVER

FIGURE 3



EVERGLADES AGRICULTURAL AREA AND MAJOR DRAINAGE CANALS
SOUTHEAST OF LAKE OKEECHOBEE

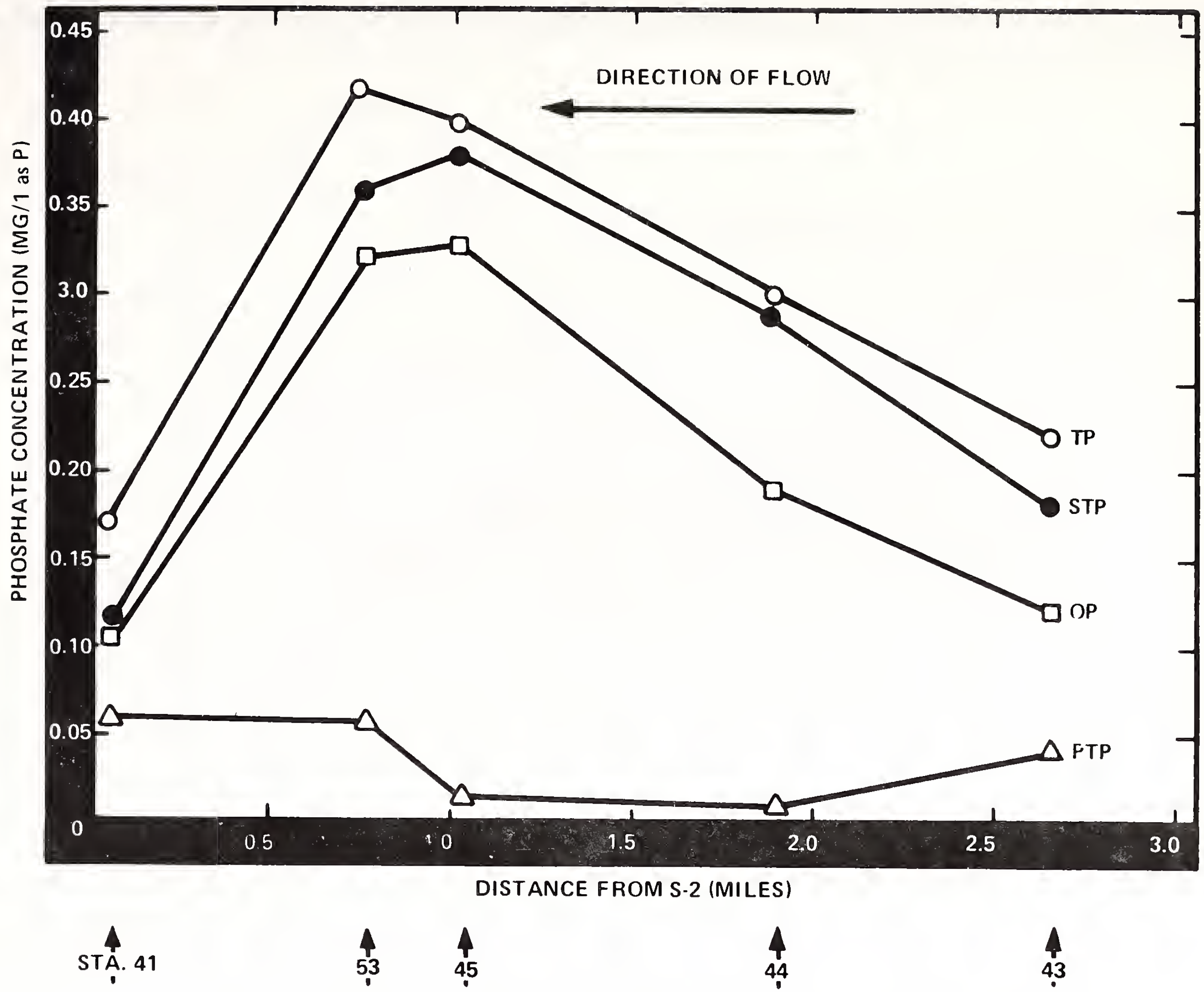
FIGURE 4



EVERGLADES AGRICULTURAL AREA S-2 AND S-3 DRAINAGE AREAS

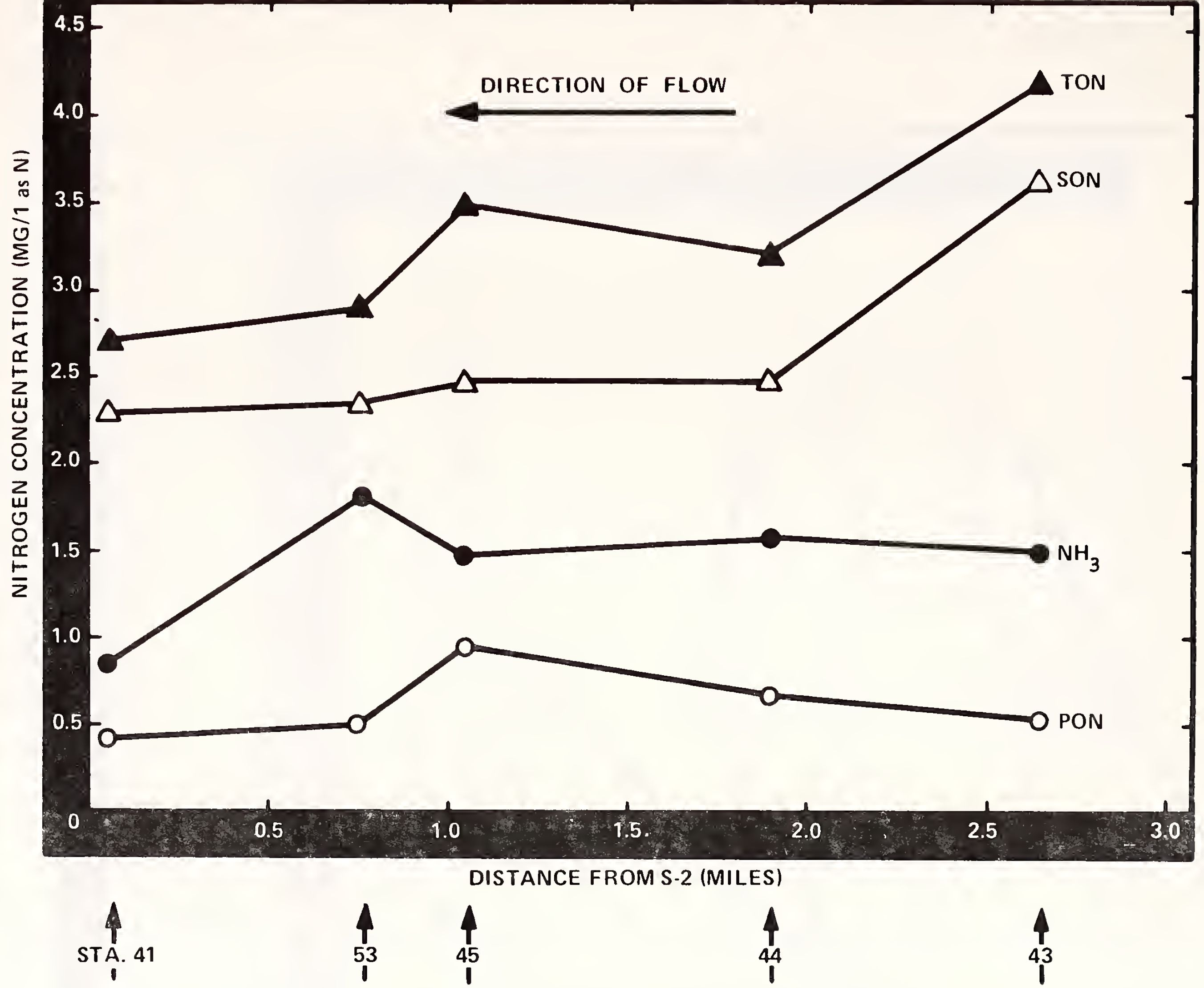
Source; From Central and Southern Flood Control District, 1975

FIGURE 5



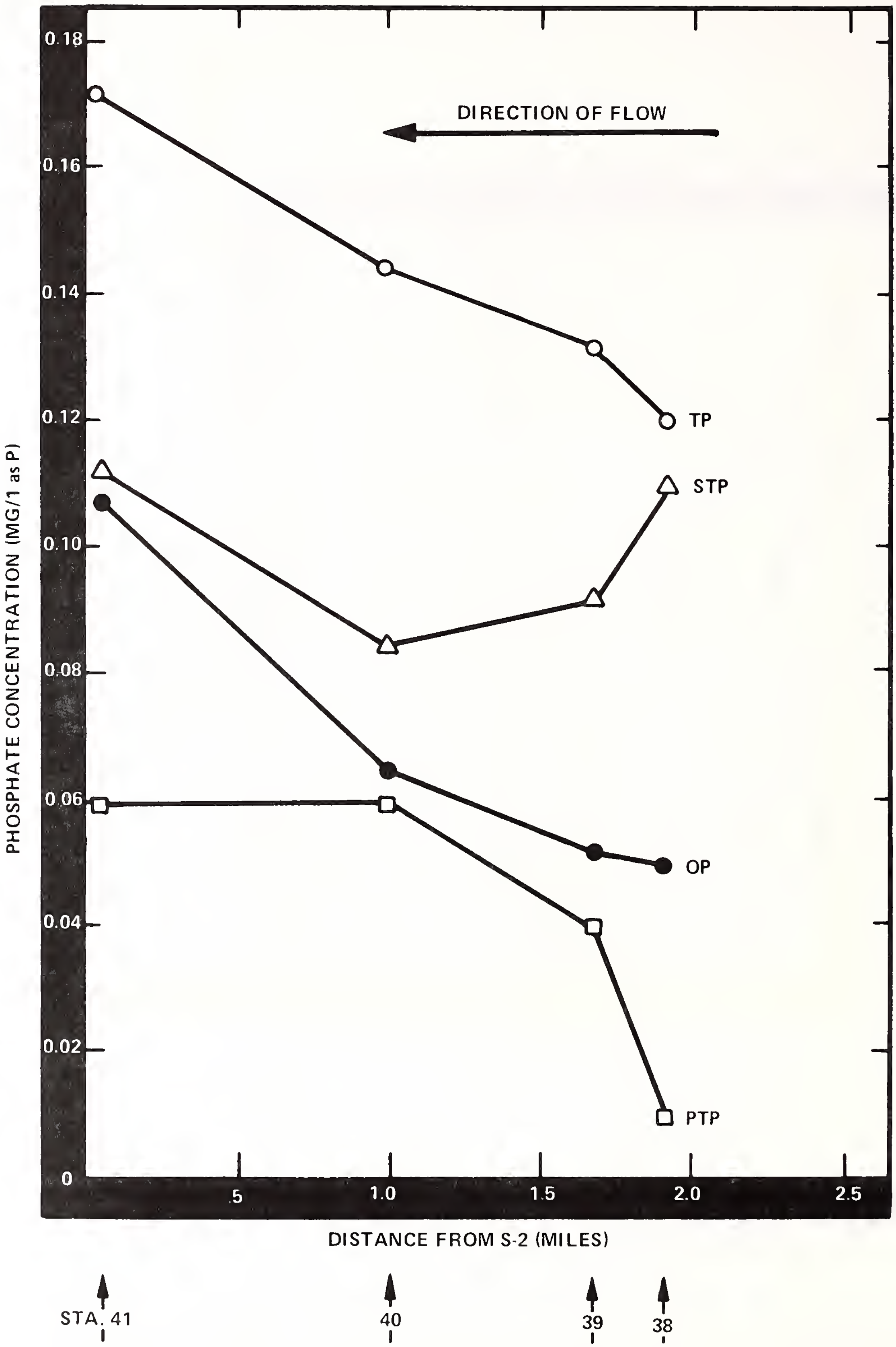
CONCENTRATIONS OF PHOSPHORUS FORMS IN HILLSBORO CANAL VS. DISTANCE FROM S-2

FIGURE 6



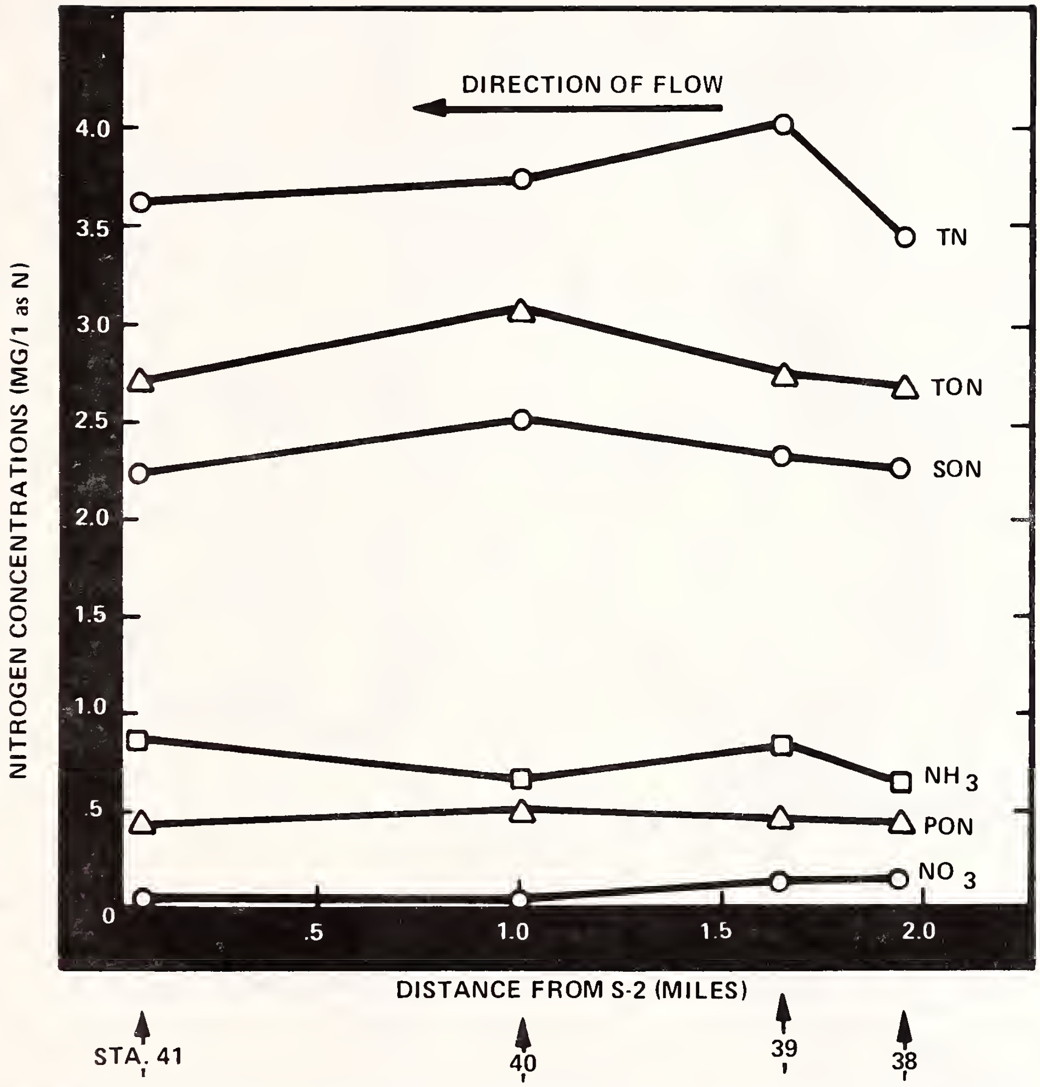
CONCENTRATIONS OF NITROGEN FORMS IN HILLSBORO CANAL VS. DISTANCE FROM S-2

FIGURE 7



CONCENTRATIONS OF PHOSPHORUS FORMS IN NORTH NEW RIVER CANAL VS. DISTANCE FROM S-2

FIGURE 8



CONCENTRATIONS OF NITROGEN FORMS IN NORTH NEW RIVER CANAL VS. DISTANCE FROM S-2

FIGURE 9

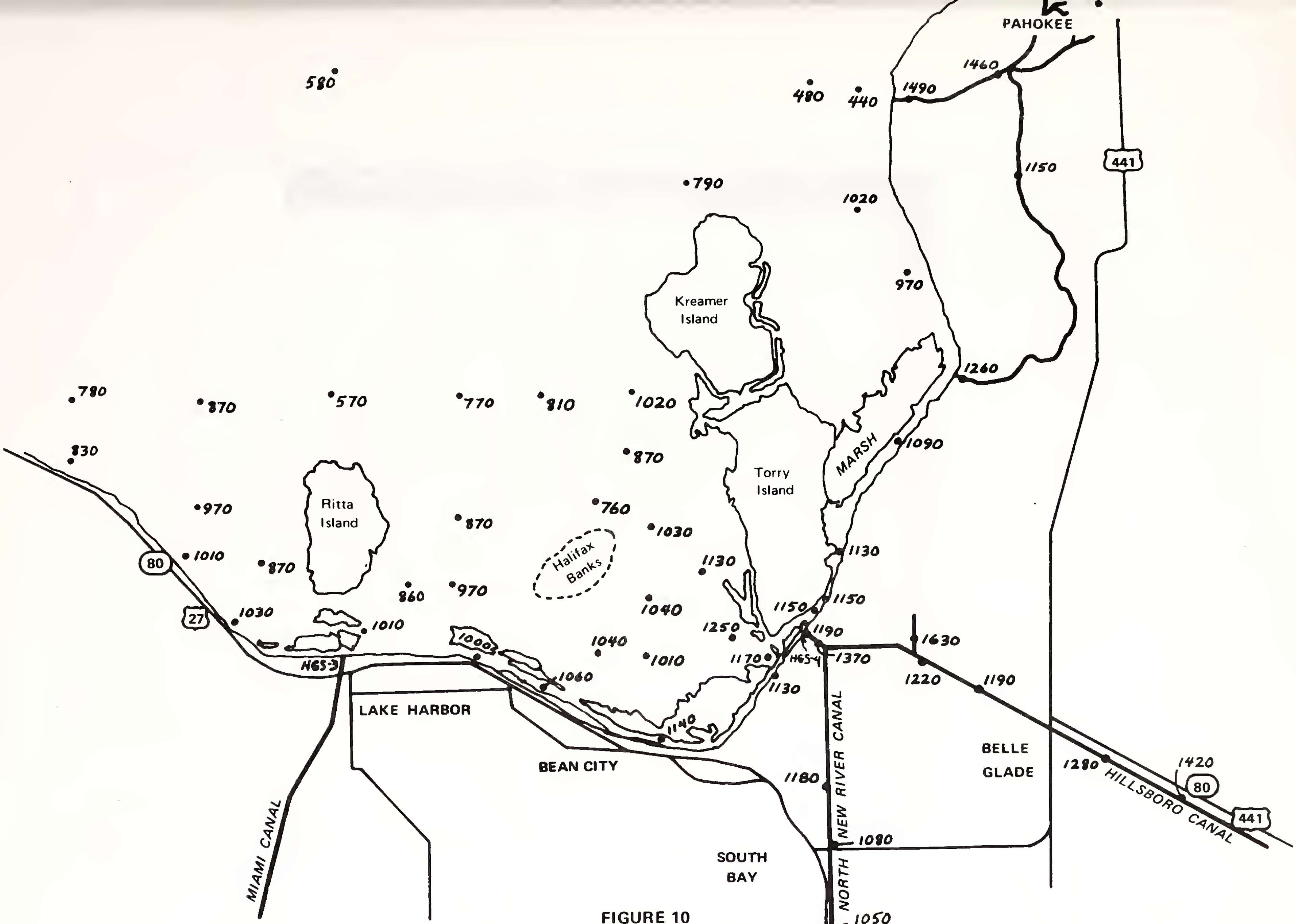


FIGURE 10

DISTRIBUTION OF SPECIFIC CONDUCTANCE IN LAKE AND CANAL STATIONS, AUG. 5, 1974

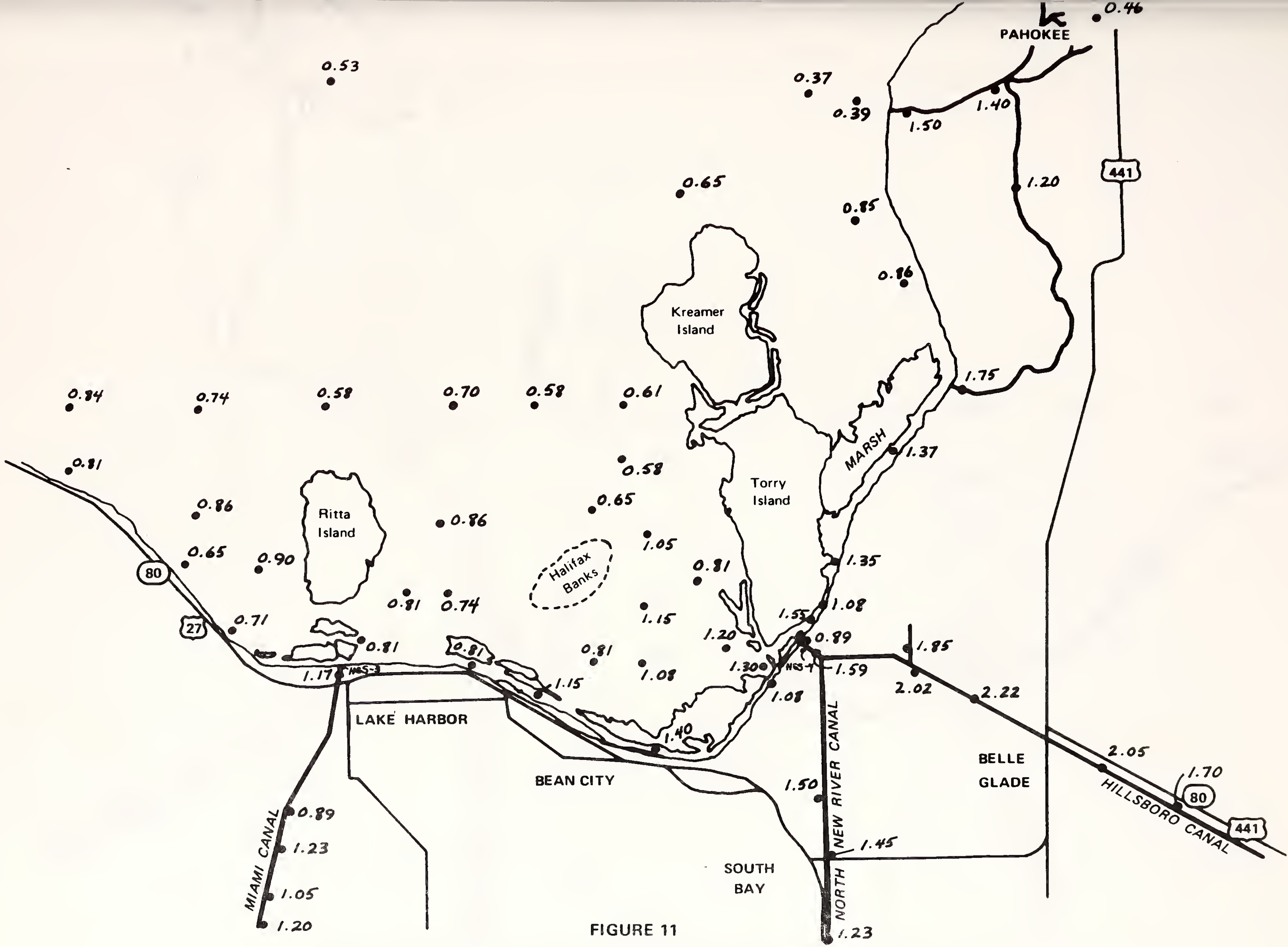


FIGURE 11

DISTRIBUTION OF FLUORIDE IN LAKE AND CANAL STATIONS

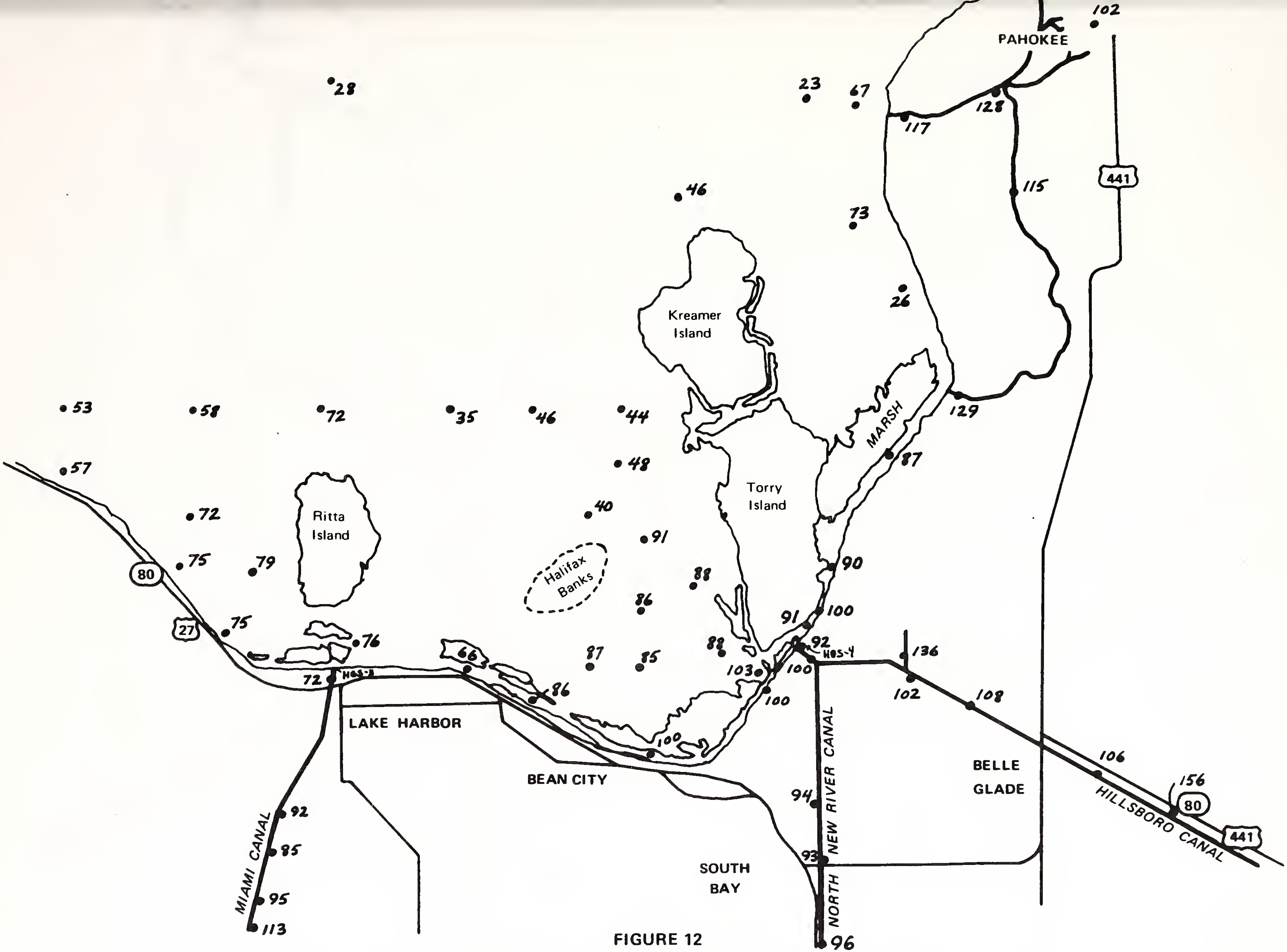


FIGURE 12

DISTRIBUTION OF TOTAL ORGANIC CARBON (TOC) IN LAKE AND CANAL STATIONS

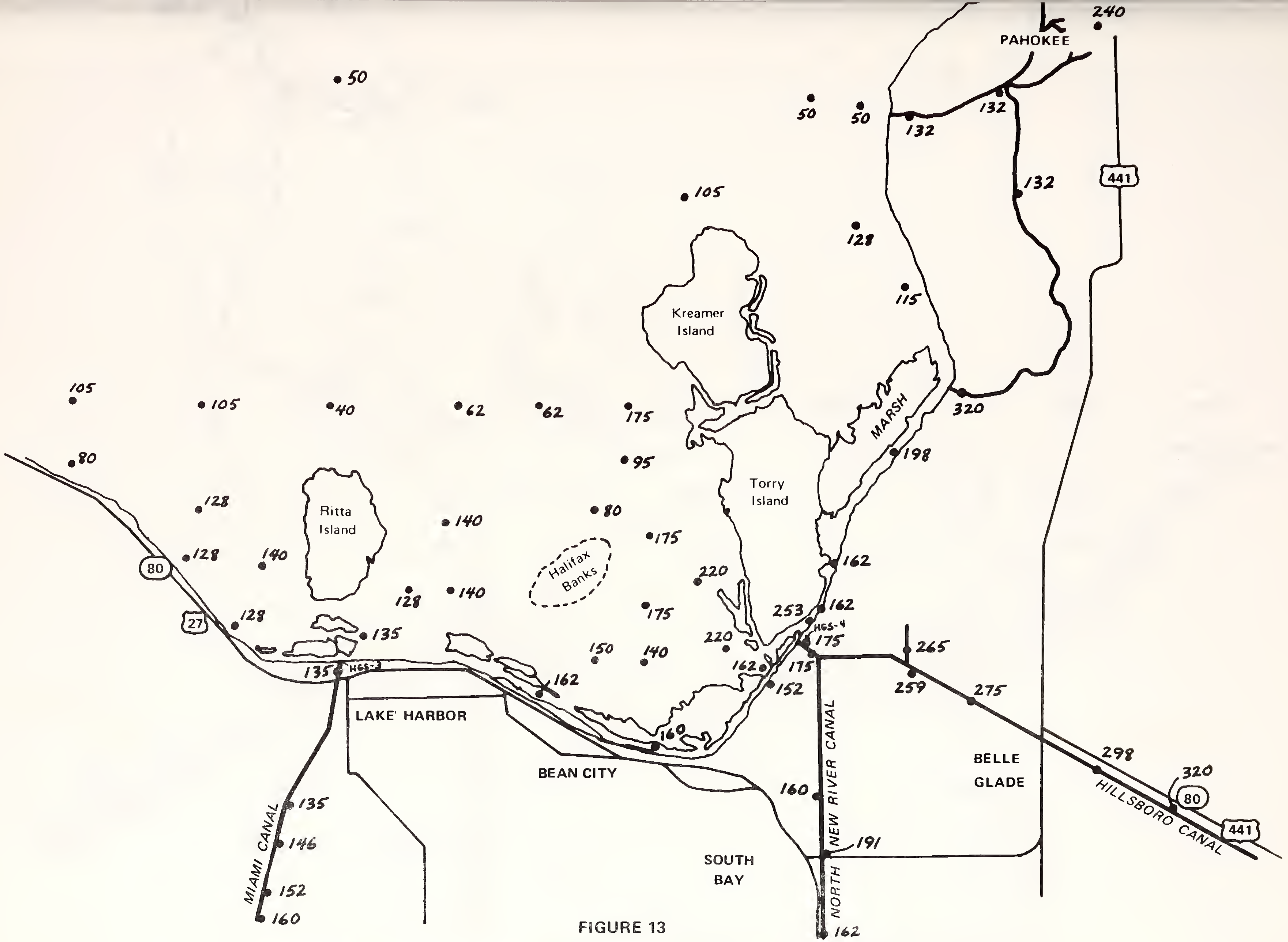


FIGURE 13

DISTRIBUTION OF COLOR IN LAKE AND CANAL STATIONS

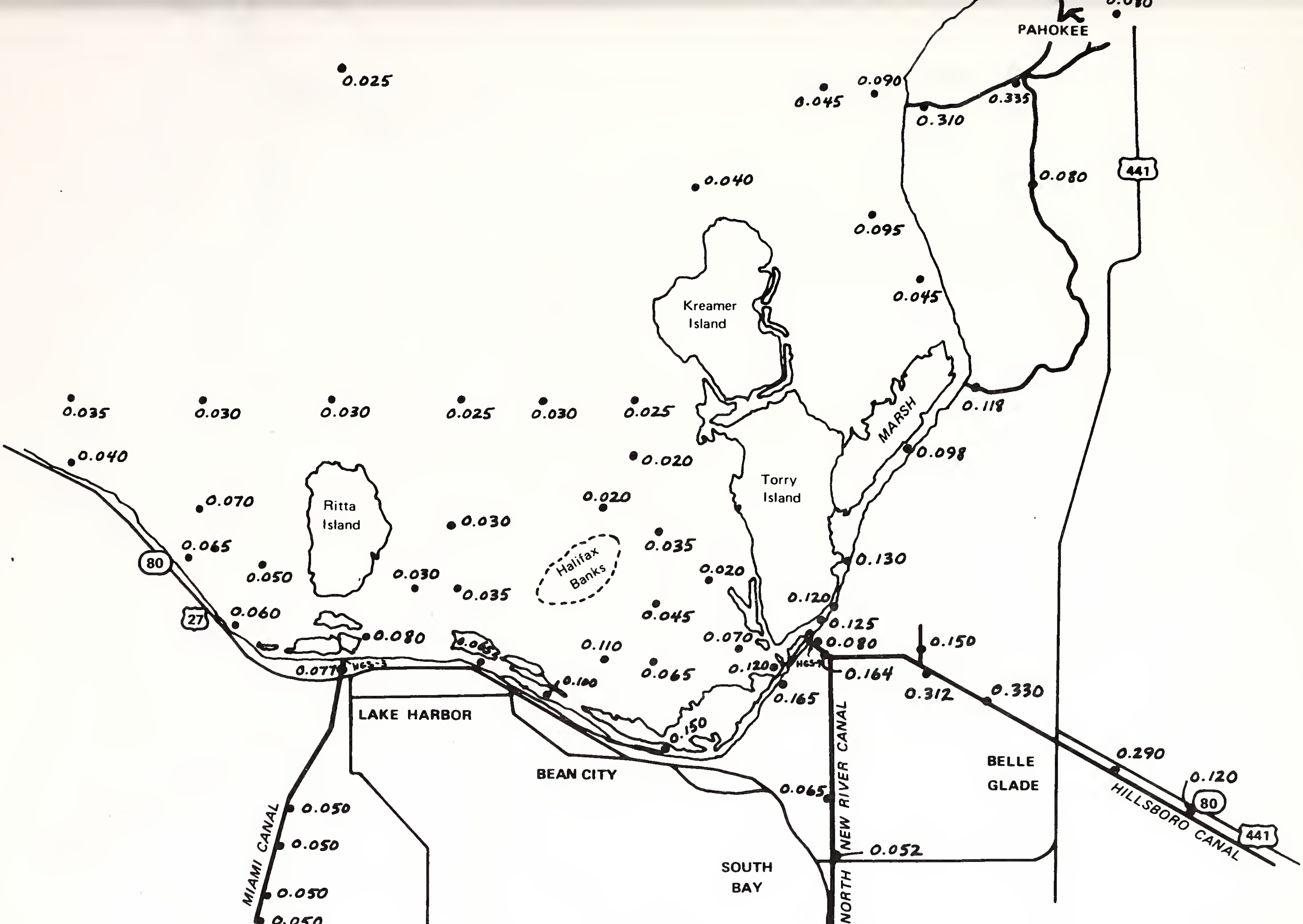


FIGURE 14

DISTRIBUTION OF SOLUBLE ORTHOPHOSPHATE IN LAKE AND CANAL STATIONS

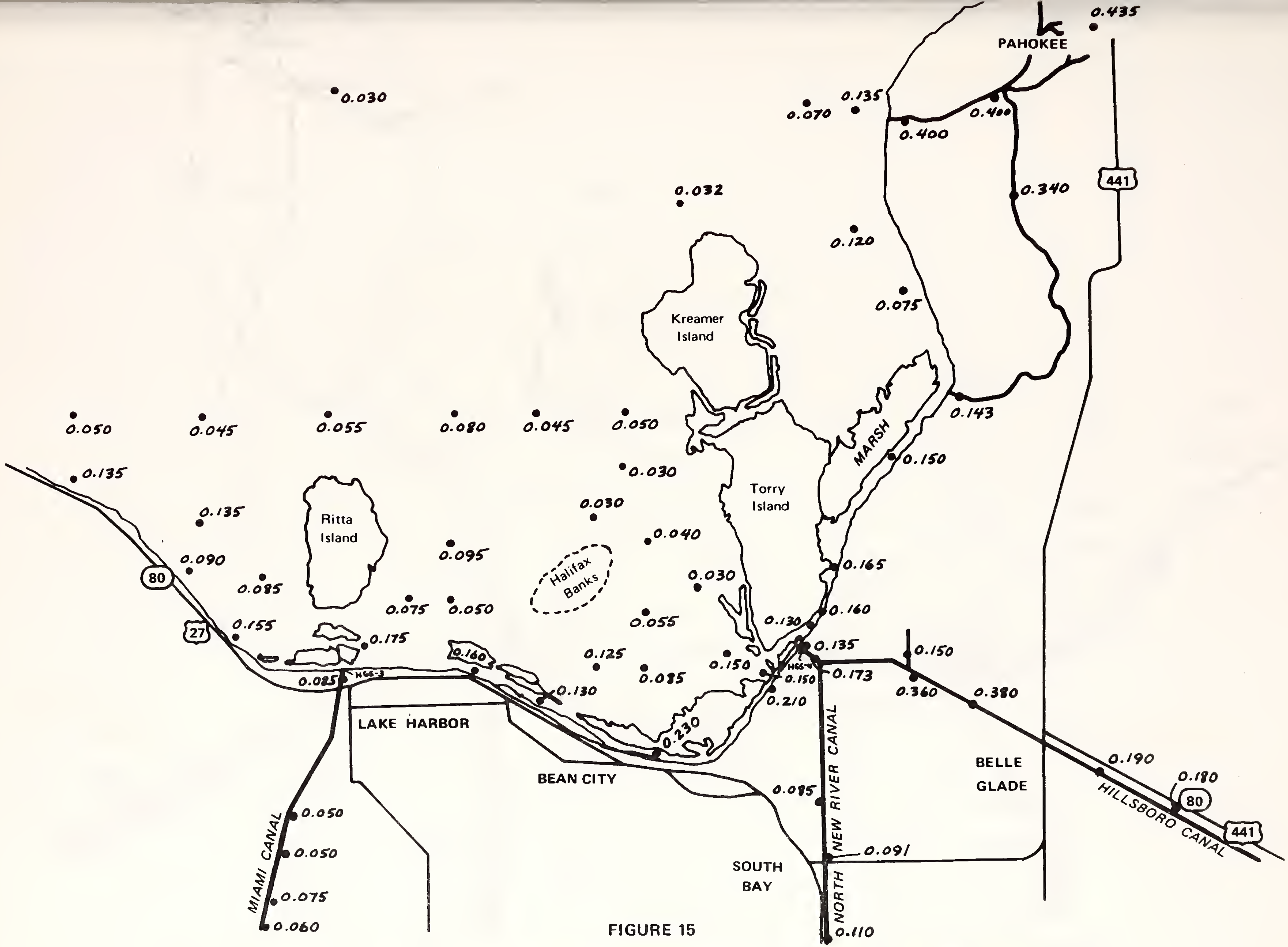


FIGURE 15

DISTRIBUTION OF TOTAL SOLUBLE PHOSPHATE IN LAKE AND CANAL STATIONS

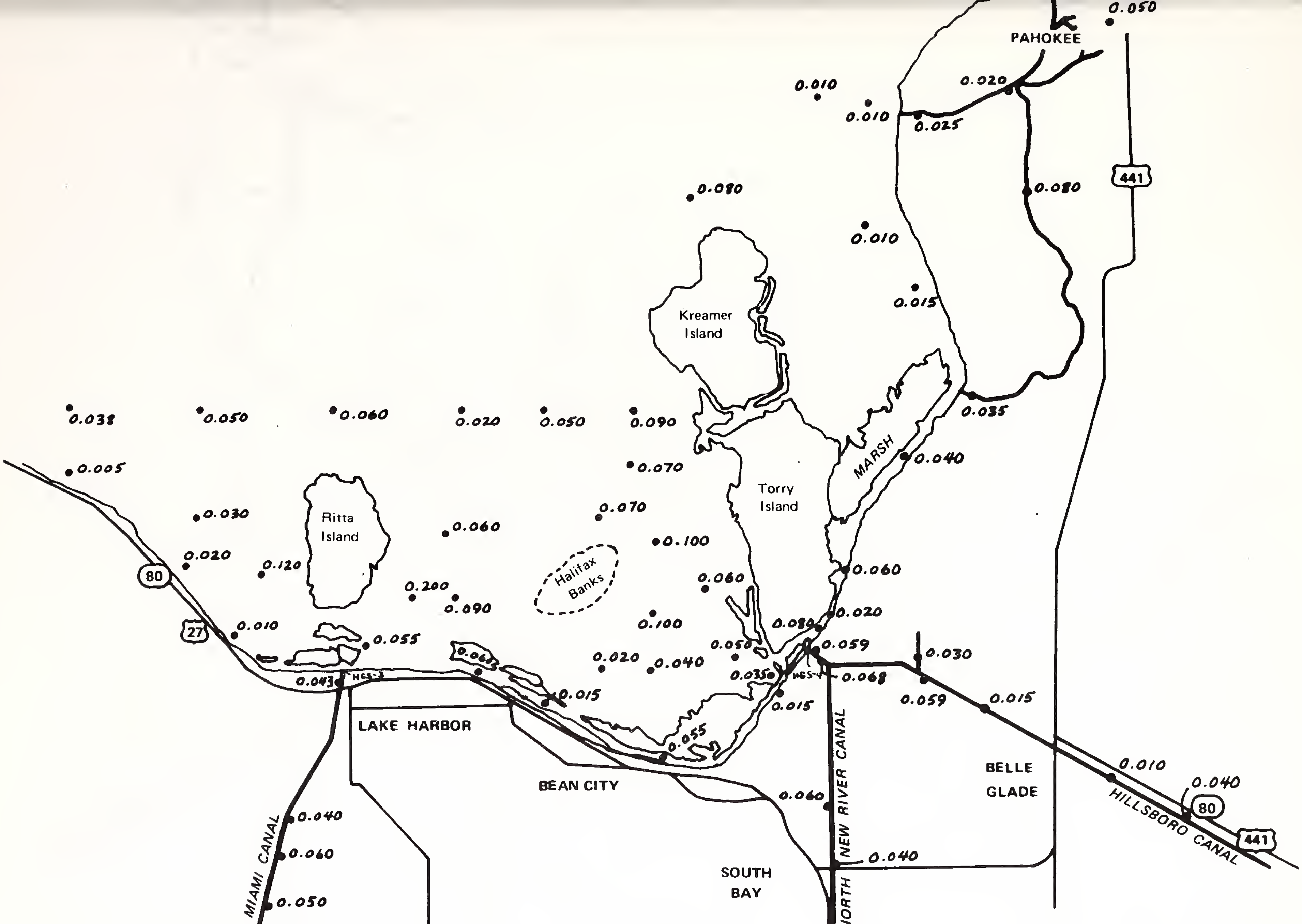


FIGURE 16

DISTRIBUTION OF TOTAL PARTICULATE PHOSPHATE IN LAKE AND CANAL STATIONS

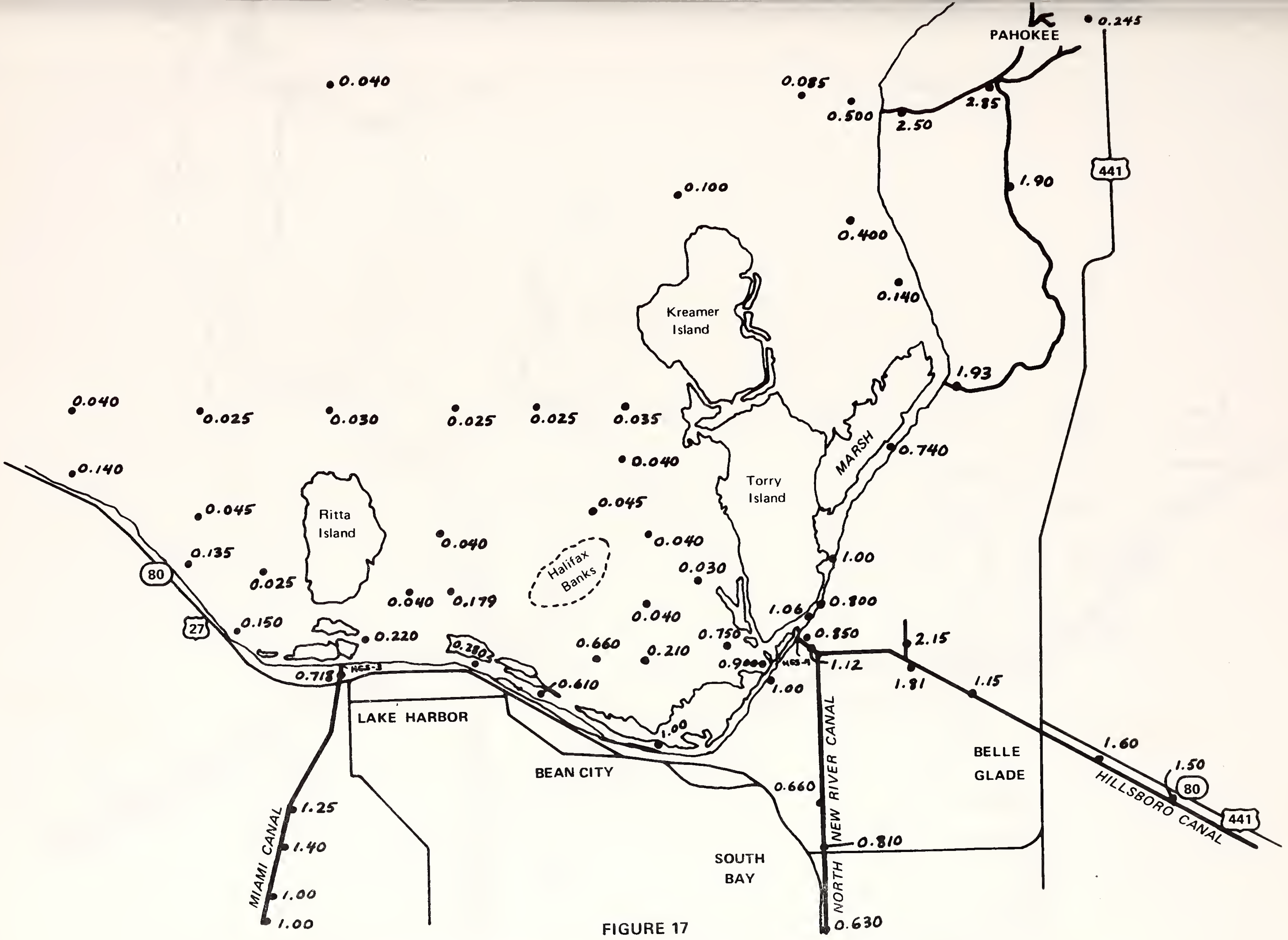


FIGURE 17

DISTRIBUTION OF AMMONIA IN LAKE AND CANAL STATIONS

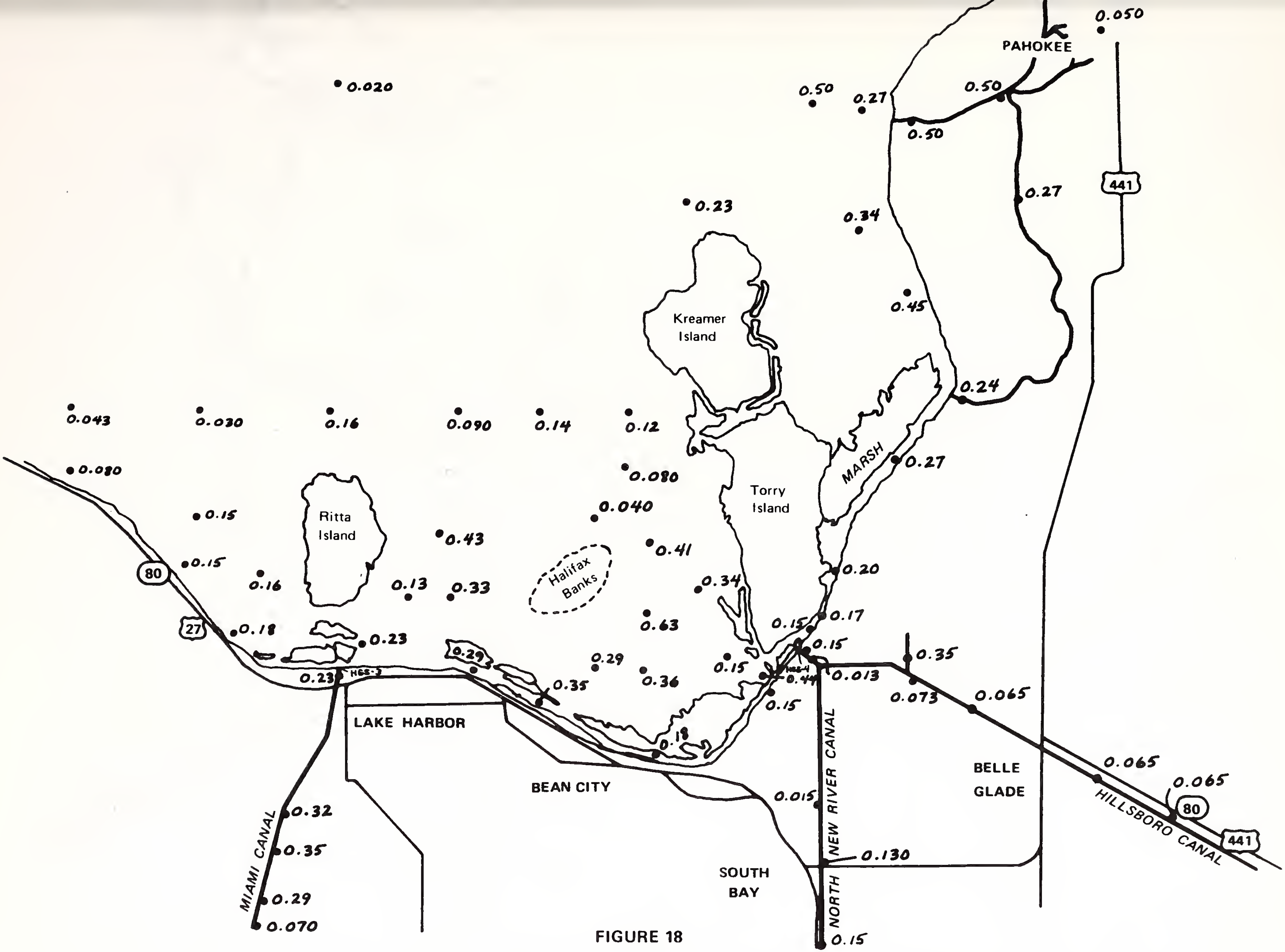


FIGURE 18

DISTRIBUTION OF NITRATE IN LAKE AND CANAL STATIONS

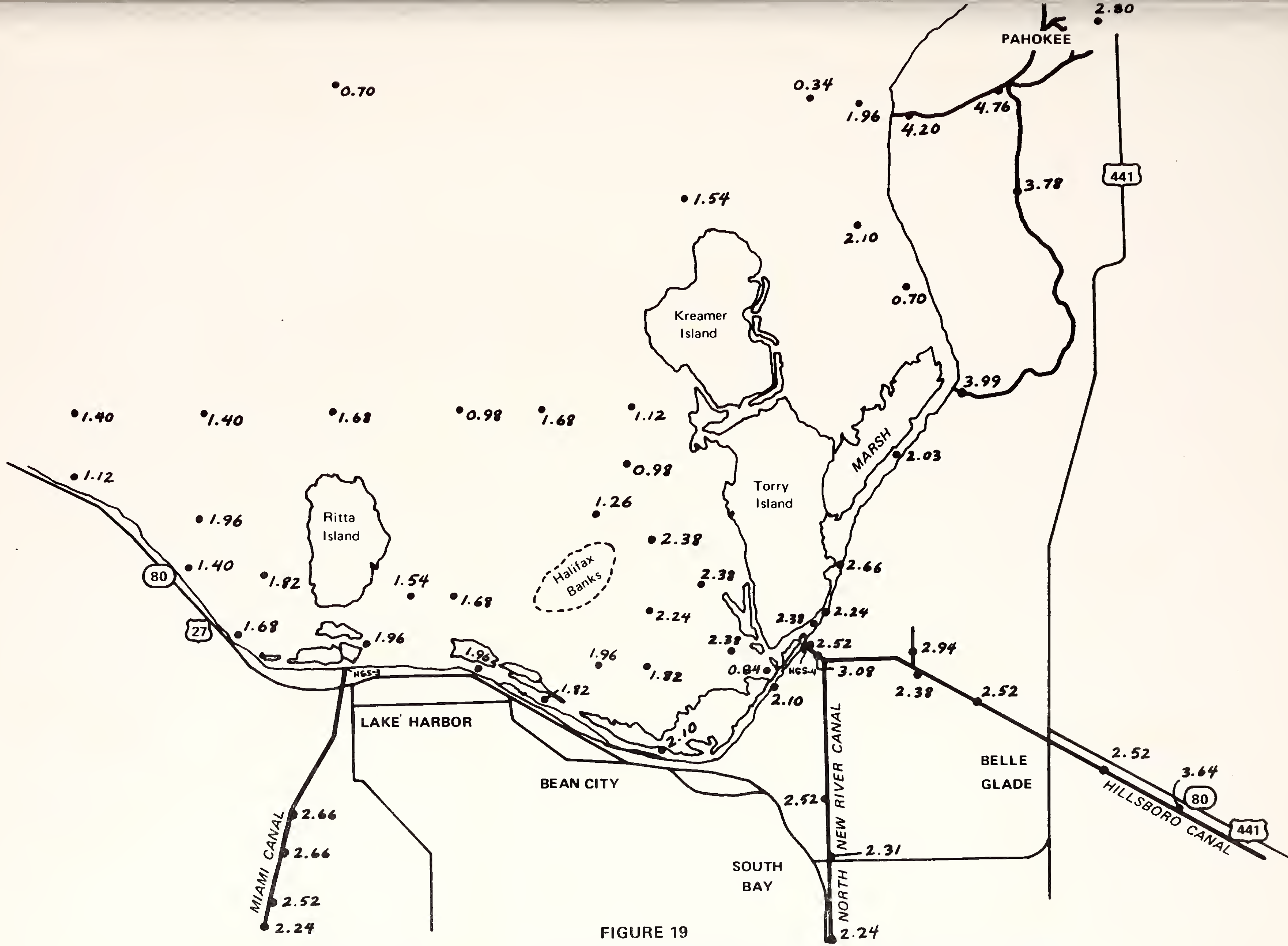
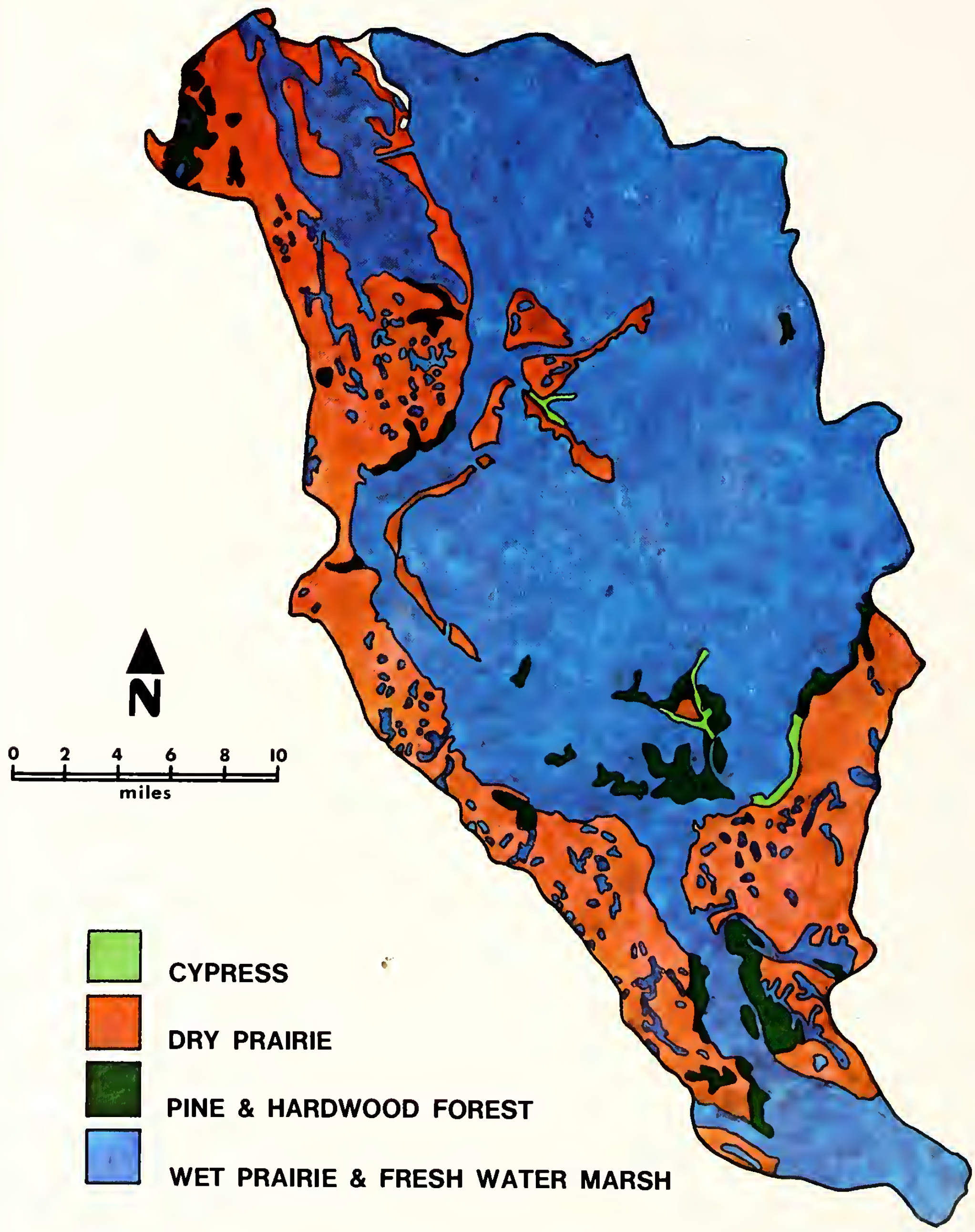


FIGURE 19

DISTRIBUTION OF SOLUBLE ORGANIC NITROGEN IN LAKE AND CANAL STATIONS

LOWER KISSIMMEE RIVER BASIN

vegetative patterns before development

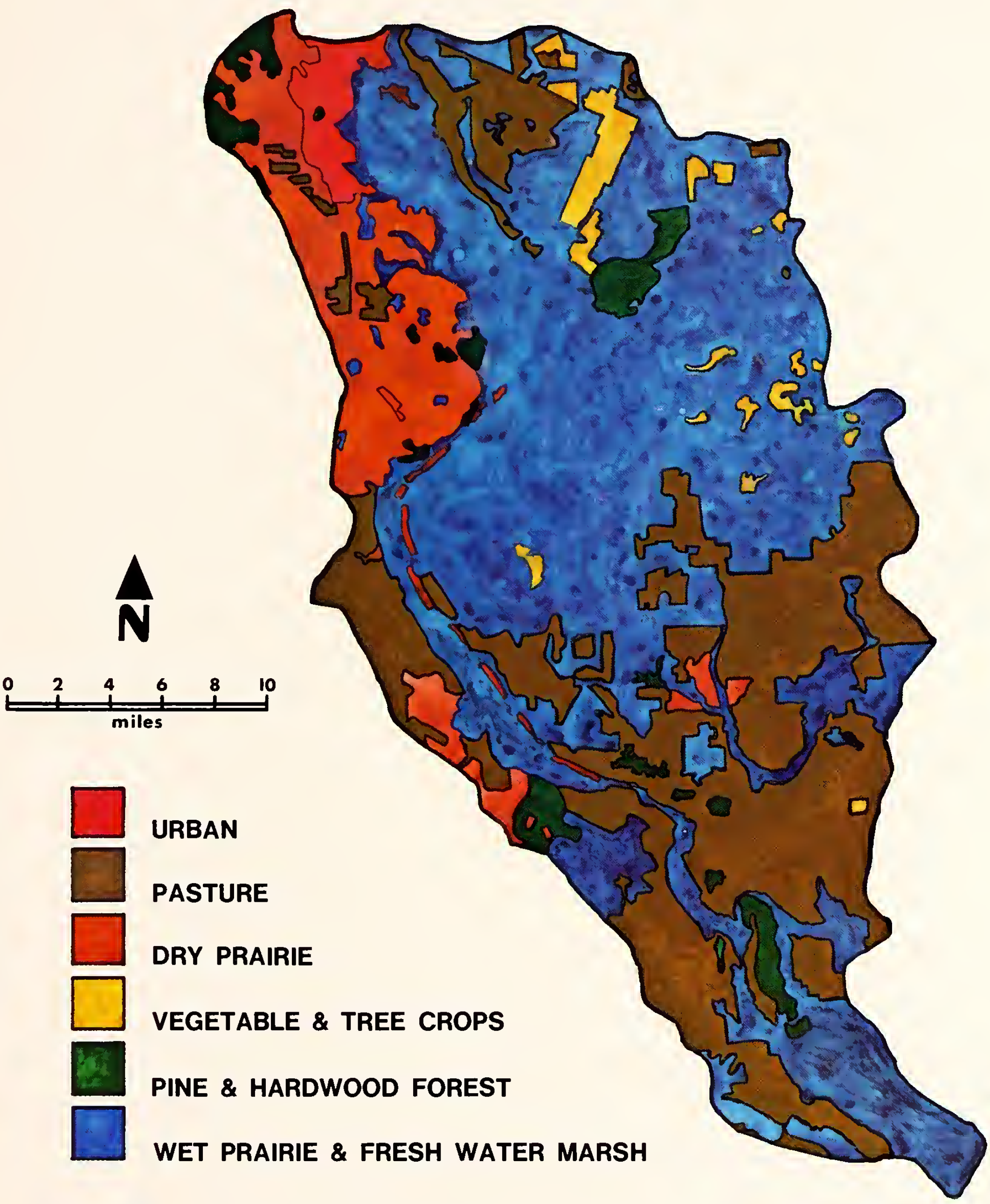


ORIGINAL MAPPING BY THE FLORIDA WETLANDS CENTER

PUBLISHED BY THE DIVISION OF STATE PLANNING

Figure 20

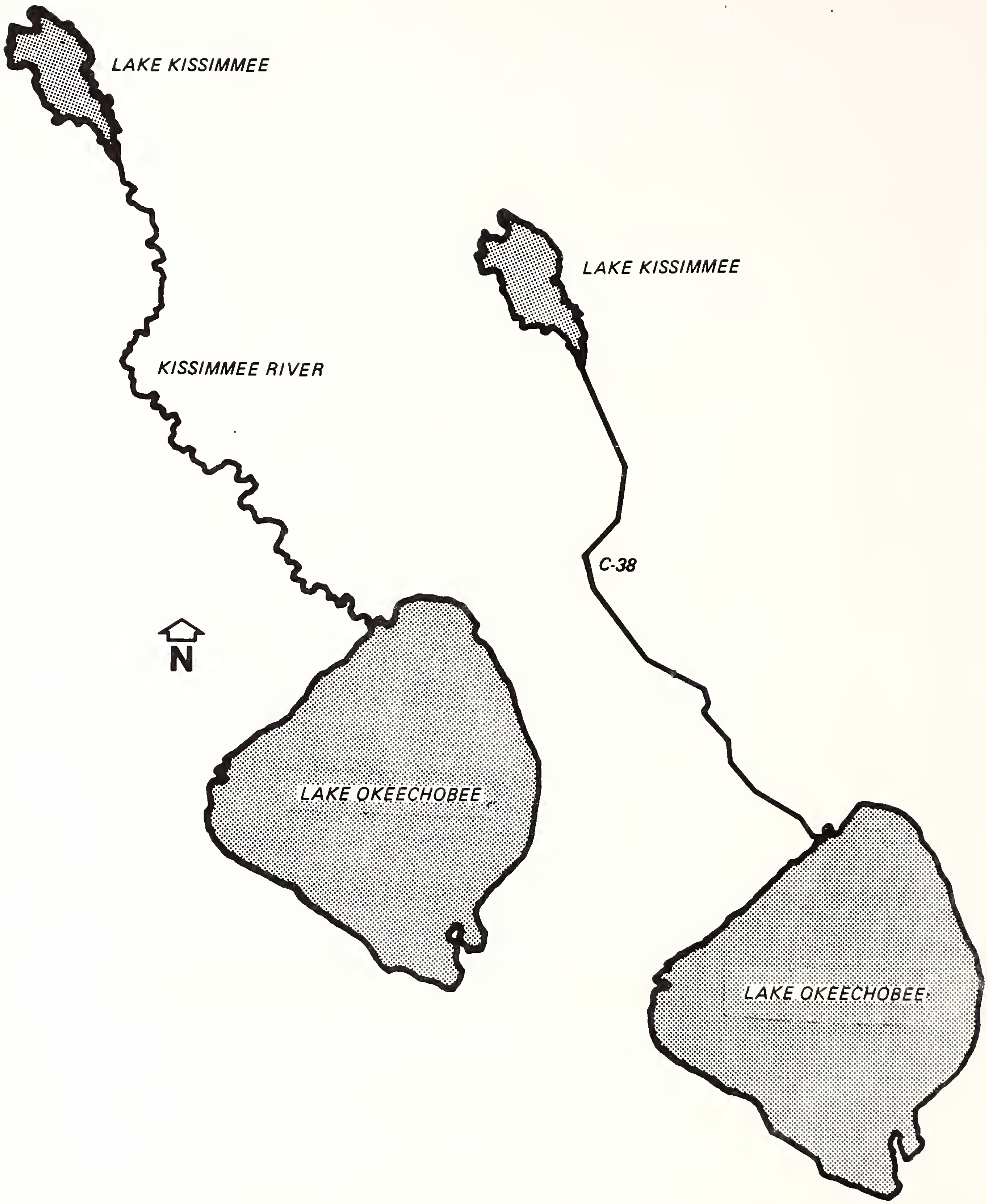
LOWER KISSIMMEE RIVER BASIN
1973 LAND USE MAP



ORIGINAL MAPPING BY THE FLORIDA WETLANDS CENTER

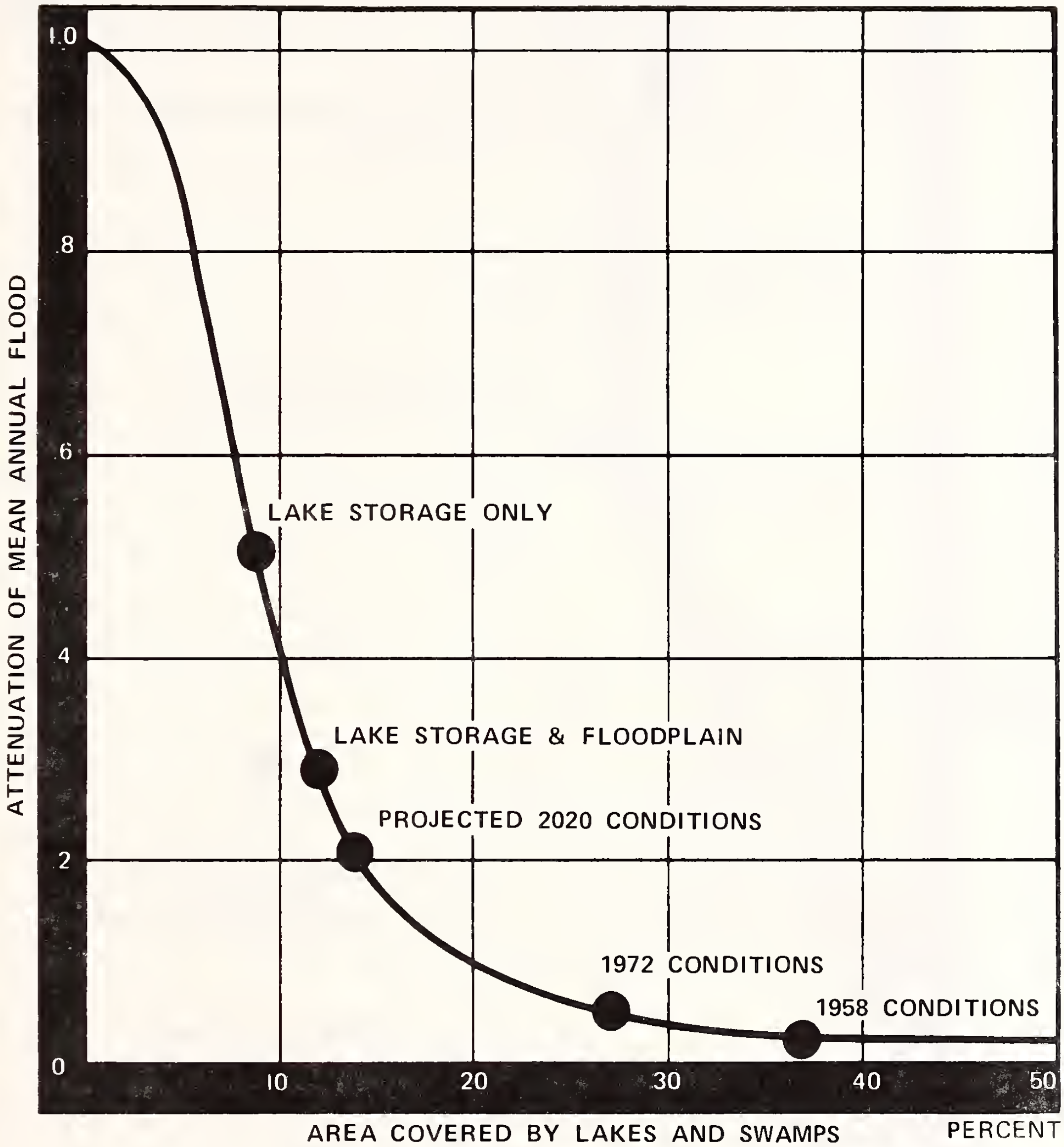
PUBLISHED BY THE DIVISION OF STATE PLANNING

Figure 21



THE KISSIMMEE RIVER BEFORE AND AFTER CHANNELIZATION

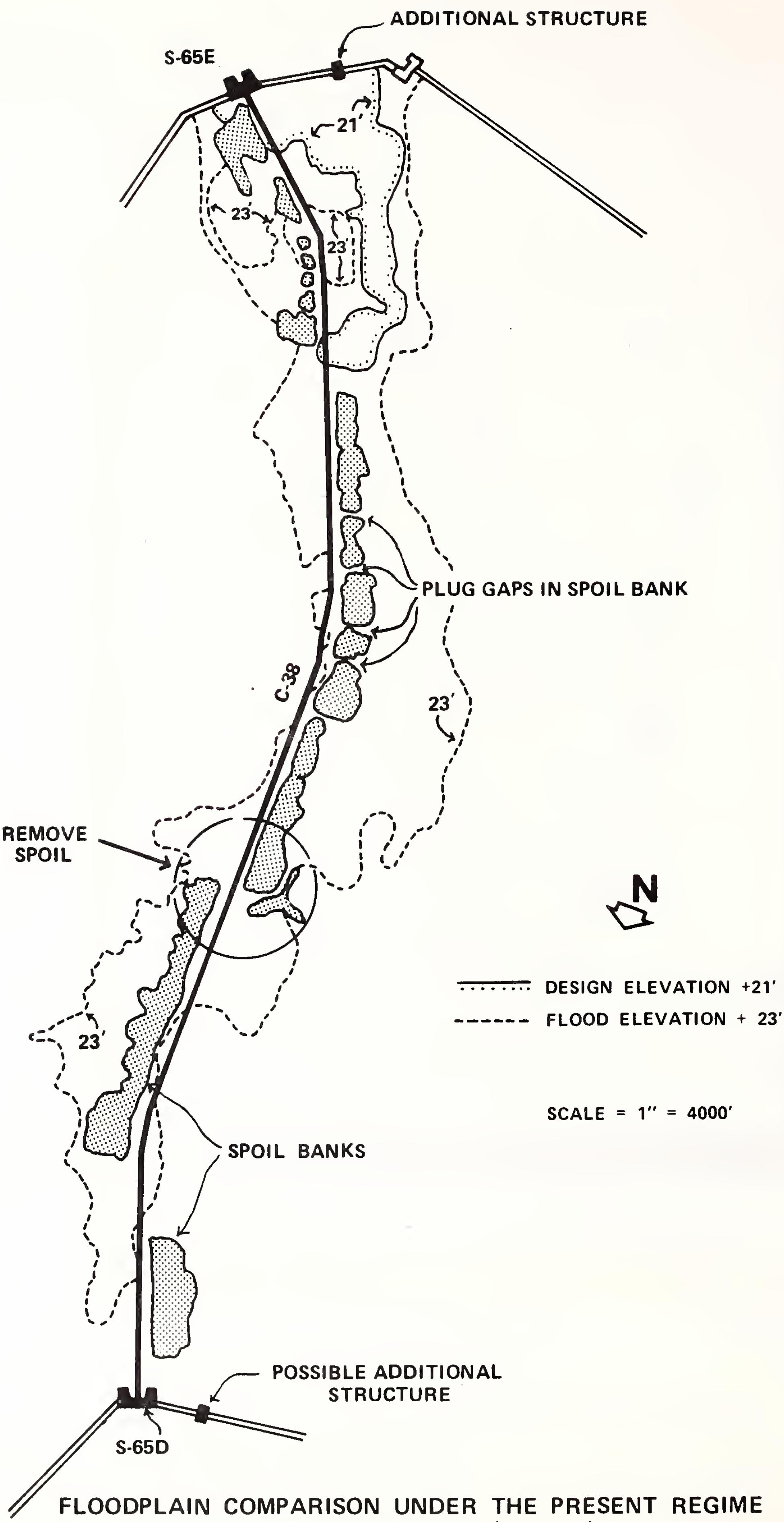
FIGURE 22



ATTENUATION OF ANNUAL FLOOD BY LAKES & SWAMPS

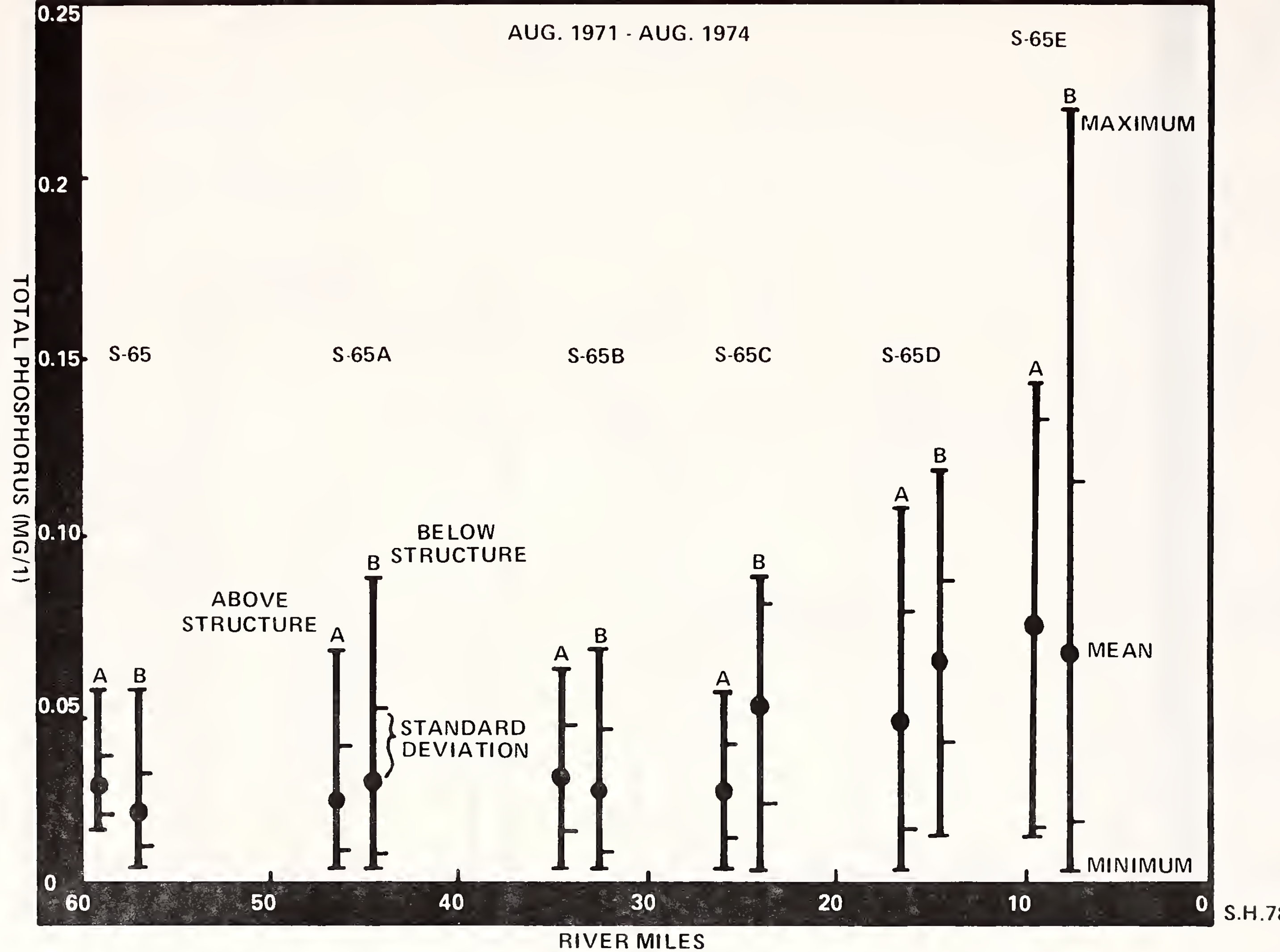
Source; Barnes and Golden, 1966

FIGURE 23



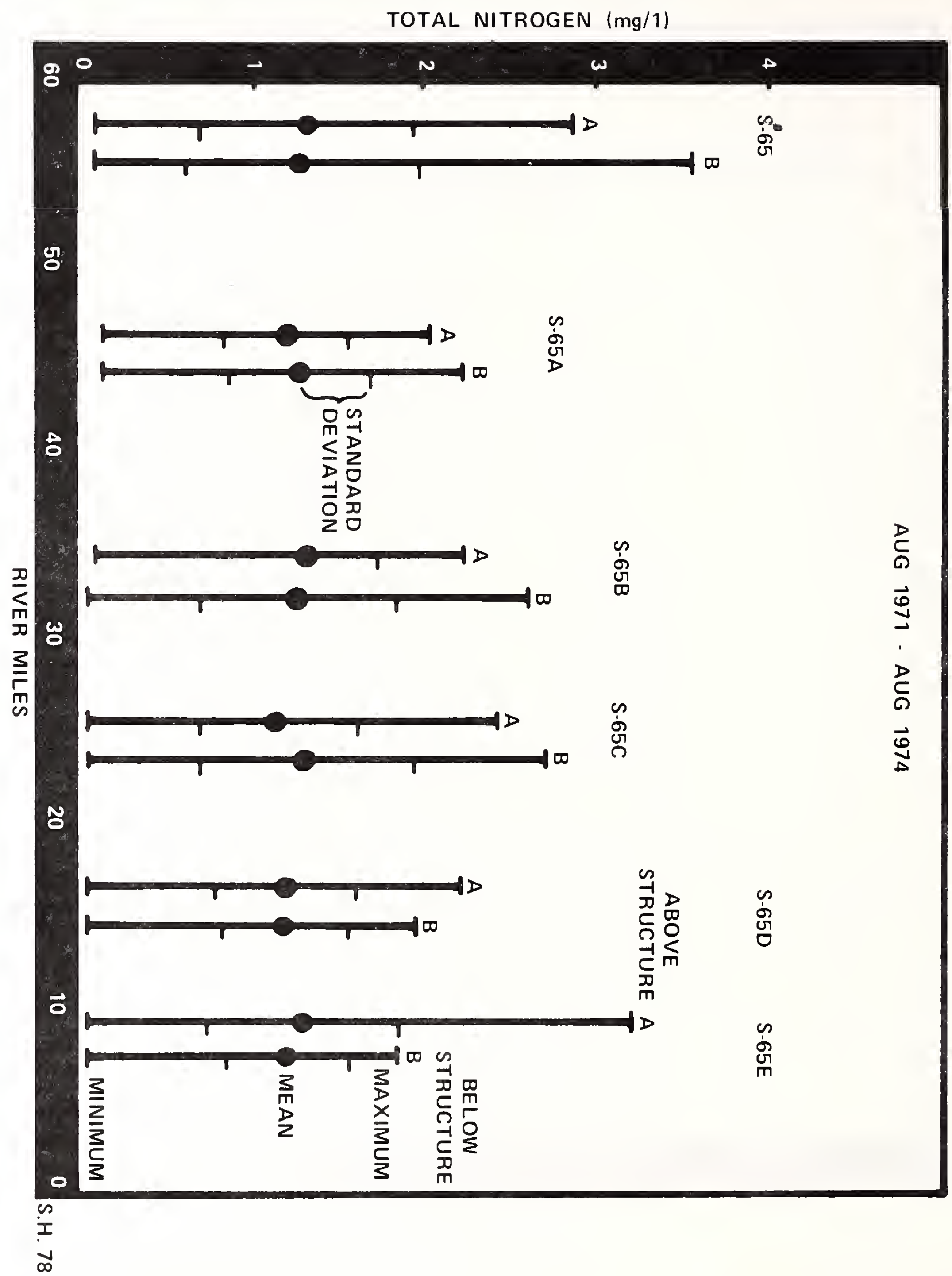
FLOODPLAIN COMPARISON UNDER THE PRESENT REGIME AND UNDER A RAISED POOL (2 FEET) REGIME

FIGURE 24



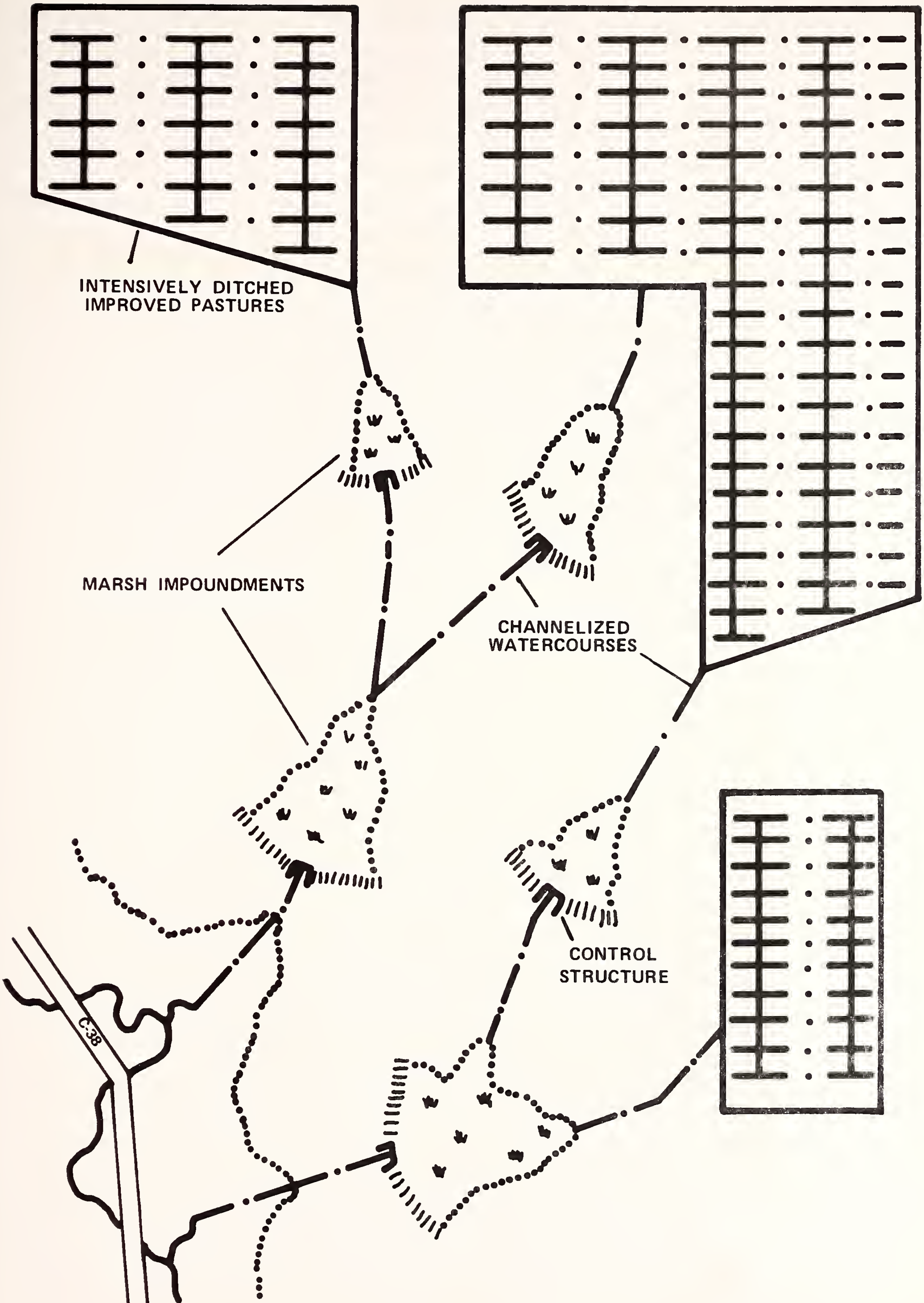
CONCENTRATION RANGE OF TOTAL PHOSPHORUS ALONG CANAL 38

FIGURE 25



CONCENTRATION RANGE OF TOTAL NITROGEN ALONG CANAL 38

FIGURE 26



ALTERNATIVE WATER CONTROL SYSTEM TO FILTER PASTURE RUNOFF

Source; GATEWOOD AND CORNWELL, 1975

FIGURE 27

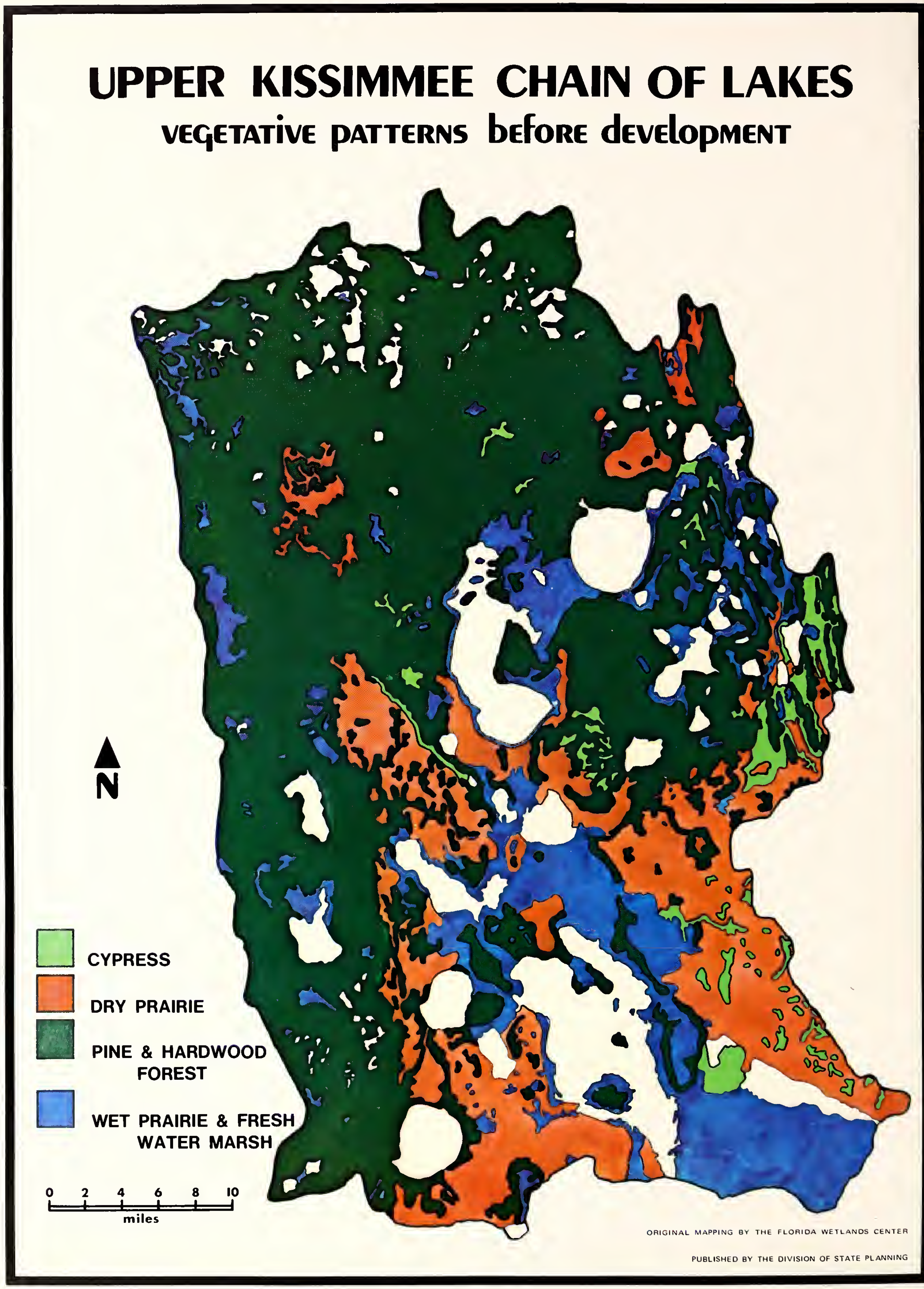

UPPER KISSIMMEE CHAIN OF LAKES
vegetative patterns before development
N
CYPRESS
DRY PRAIRIE
PINE & HARDWOOD FOREST
WET PRAIRIE & FRESH WATER MARSH
0 2 4 6 8 10
miles
ORIGINAL MAPPING BY THE FLORIDA WETLANDS CENTER
PUBLISHED BY THE DIVISION OF STATE PLANNING

Figure 28

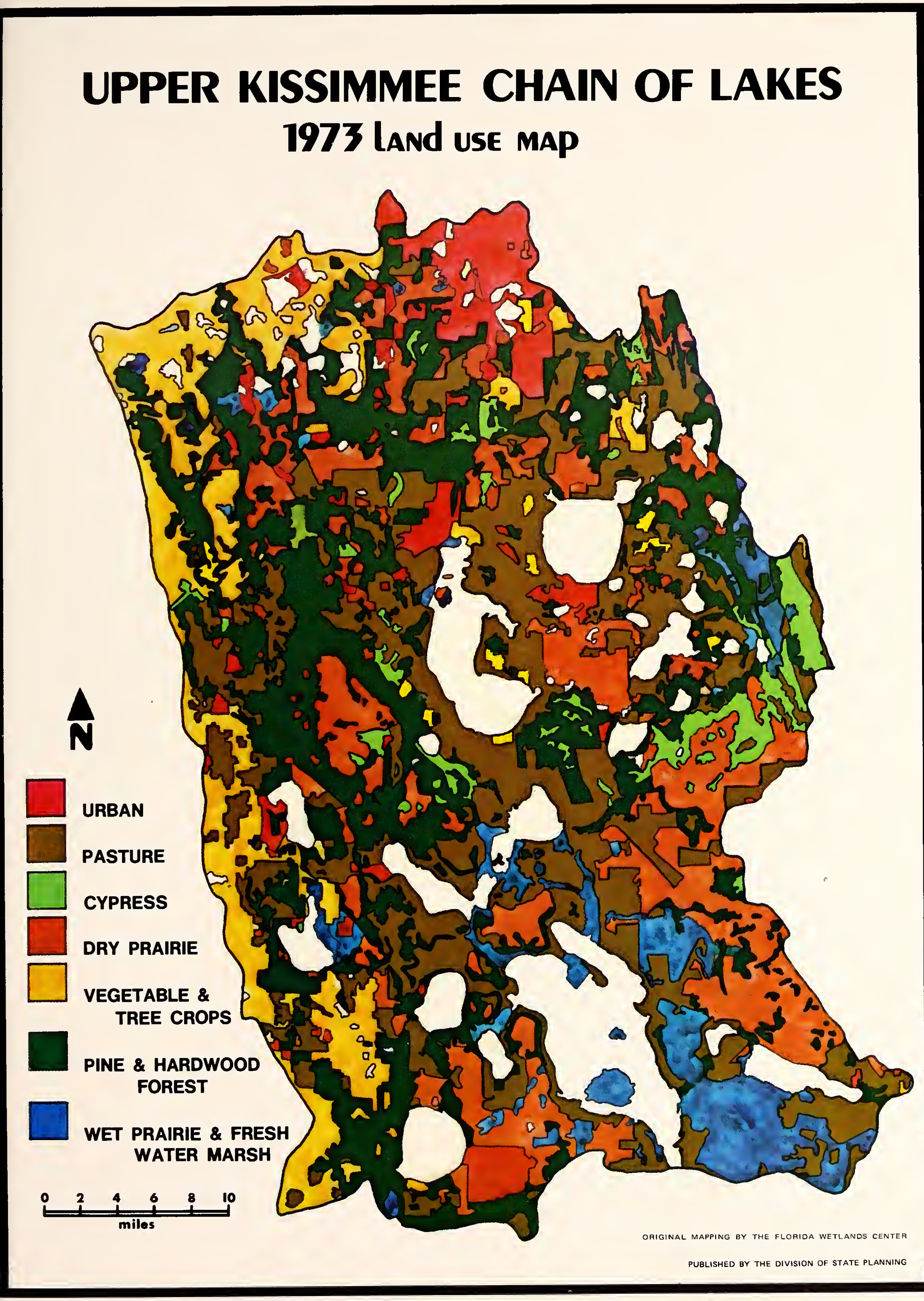

UPPER KISSIMMEE CHAIN OF LAKES
1973 LAND USE MAP
N
URBAN
PASTURE
CYPRESS
DRY PRAIRIE
VEGETABLE & TREE CROPS
PINE & HARDWOOD FOREST
WET PRAIRIE & FRESH WATER MARSH
0 2 4 6 8 10
miles
ORIGINAL MAPPING BY THE FLORIDA WETLANDS CENTER
PUBLISHED BY THE DIVISION OF STATE PLANNING

Figure 29

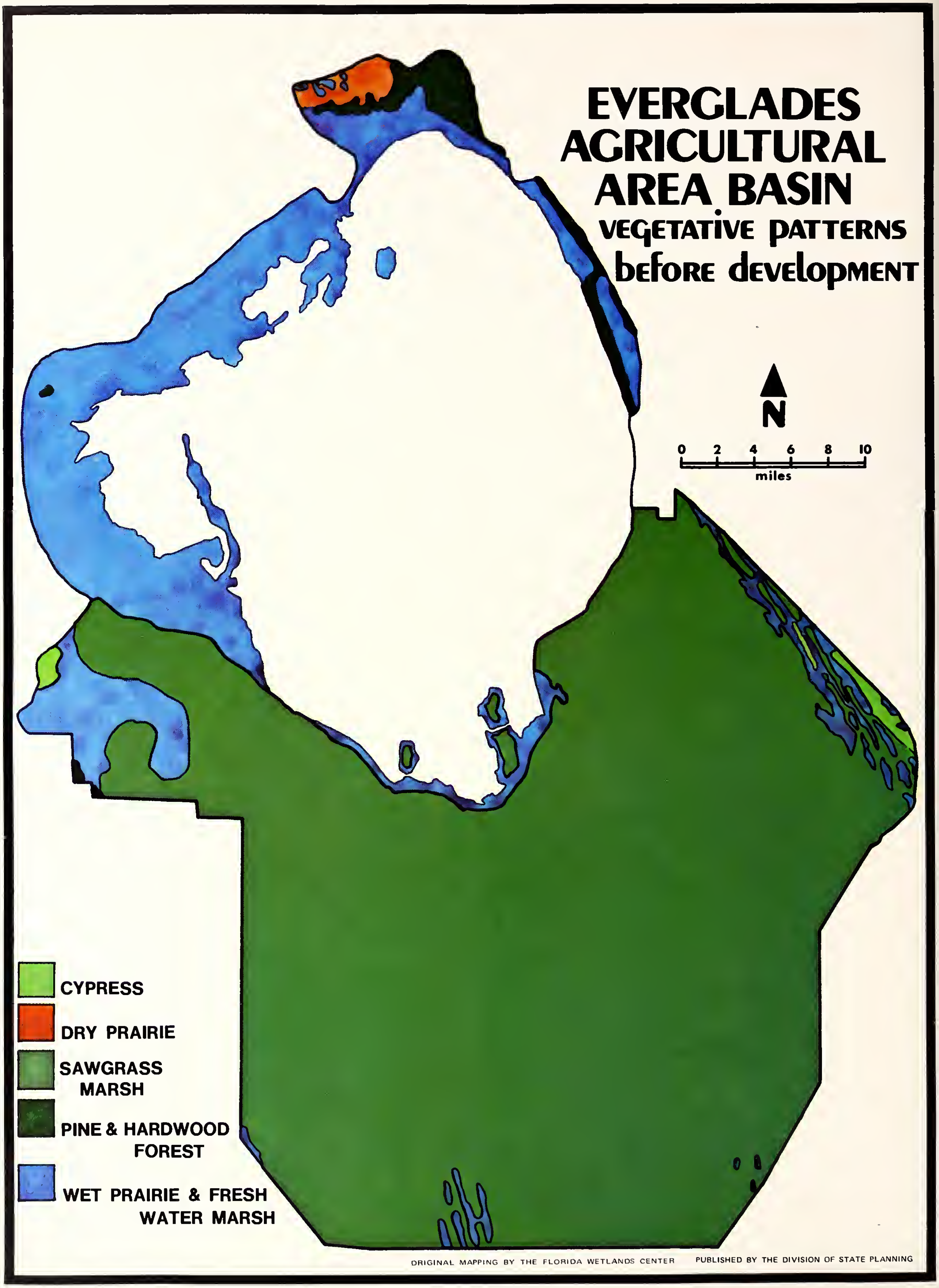

EVERGLADES
AGRICULTURAL
AREA BASIN
VEGETATIVE PATTERNS
before development
N
0 2 4 6 8 10
miles
CYPRESS
DRY PRAIRIE
SAWGRASS MARSH
PINE & HARDWOOD FOREST
WET PRAIRIE & FRESH WATER MARSH
ORIGINAL MAPPING BY THE FLORIDA WETLANDS CENTER
PUBLISHED BY THE DIVISION OF STATE PLANNING

Figure 30

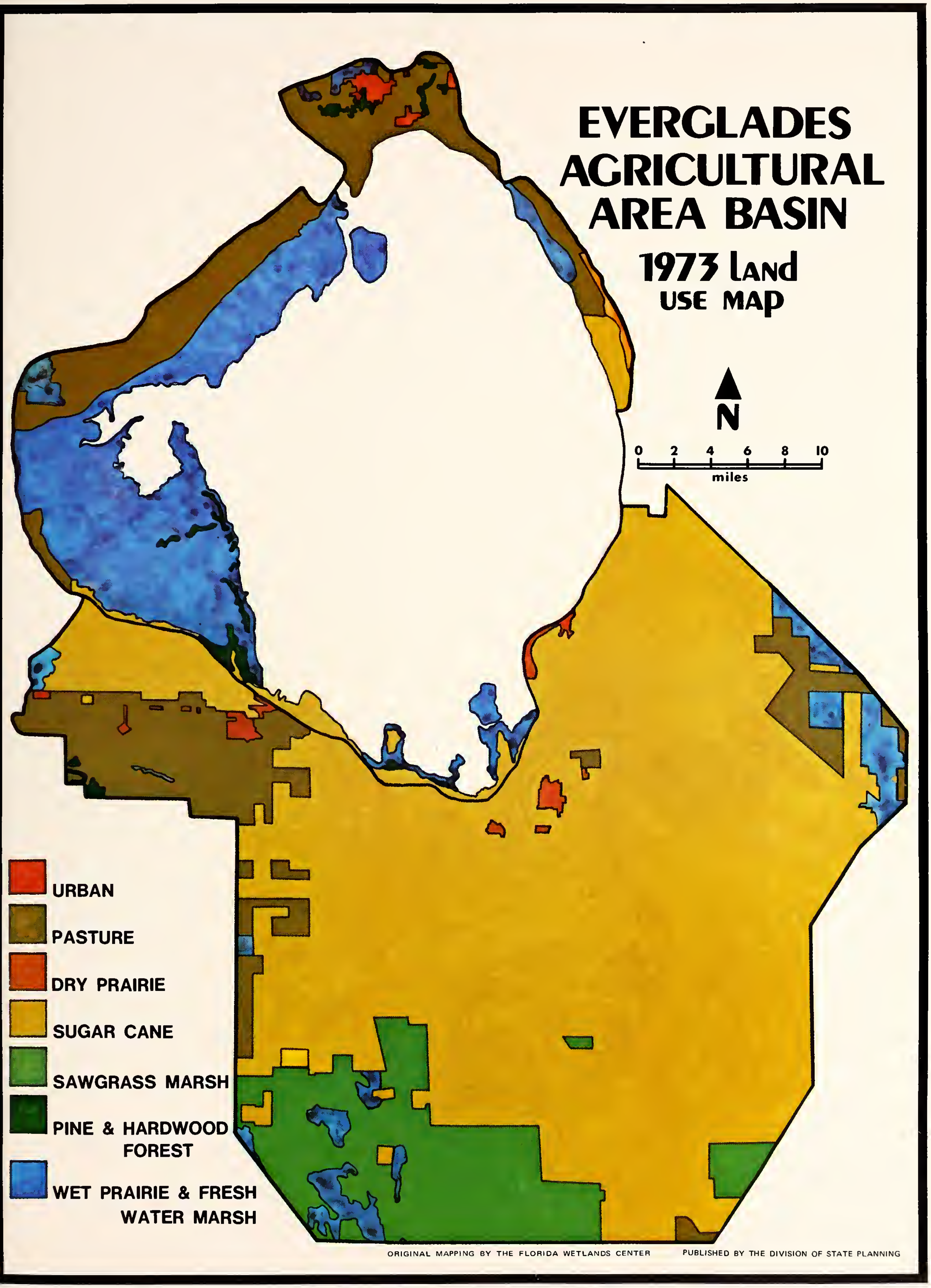
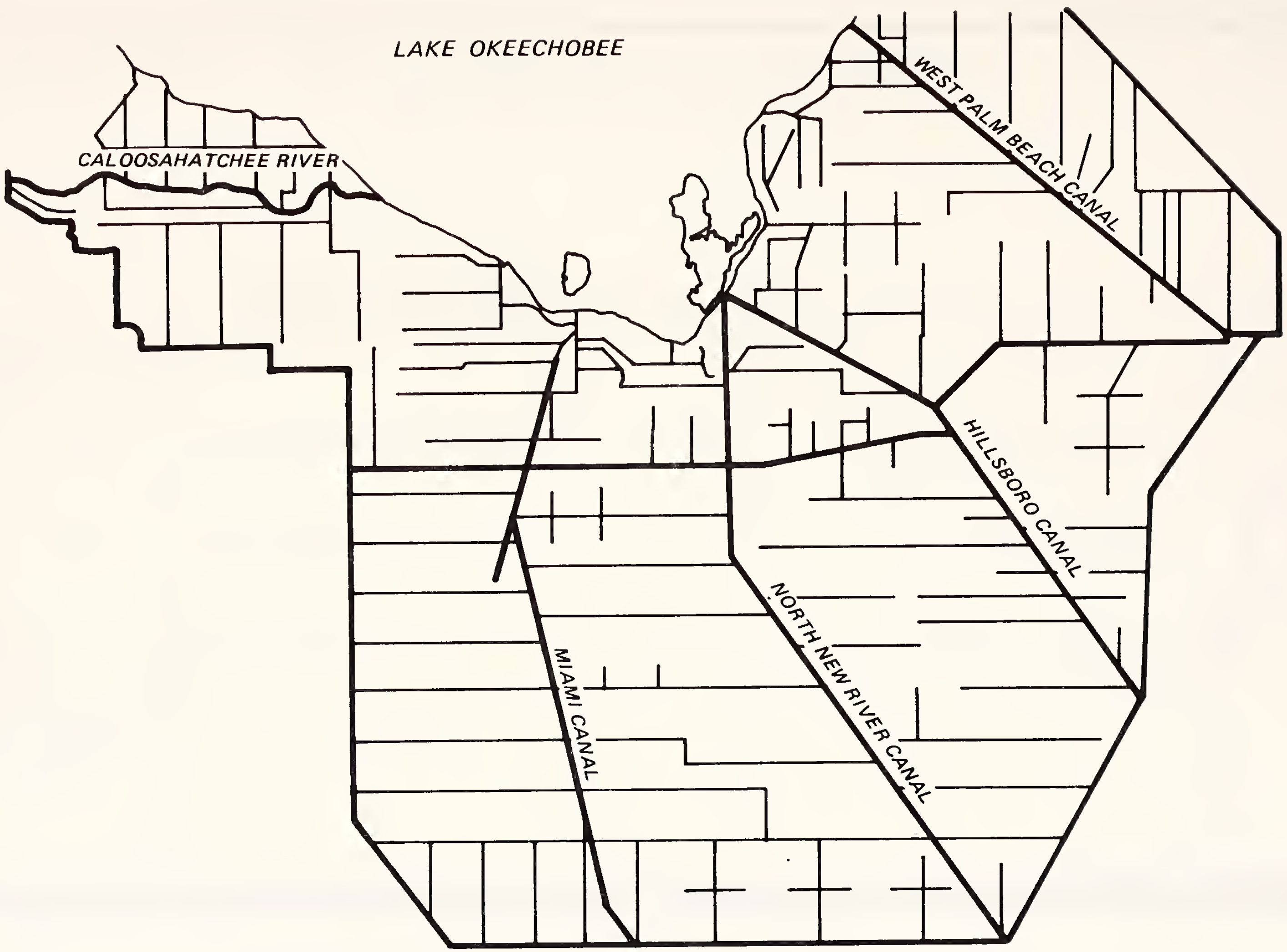

EVERGLADES AGRICULTURAL AREA BASIN
1973 LAND USE MAP
N
0 2 4 6 8 10
miles
URBAN
PASTURE
DRY PRAIRIE
SUGAR CANE
SAWGRASS MARSH
PINE & HARDWOOD FOREST
WET PRAIRIE & FRESH WATER MARSH
ORIGINAL MAPPING BY THE FLORIDA WETLANDS CENTER
PUBLISHED BY THE DIVISION OF STATE PLANNING

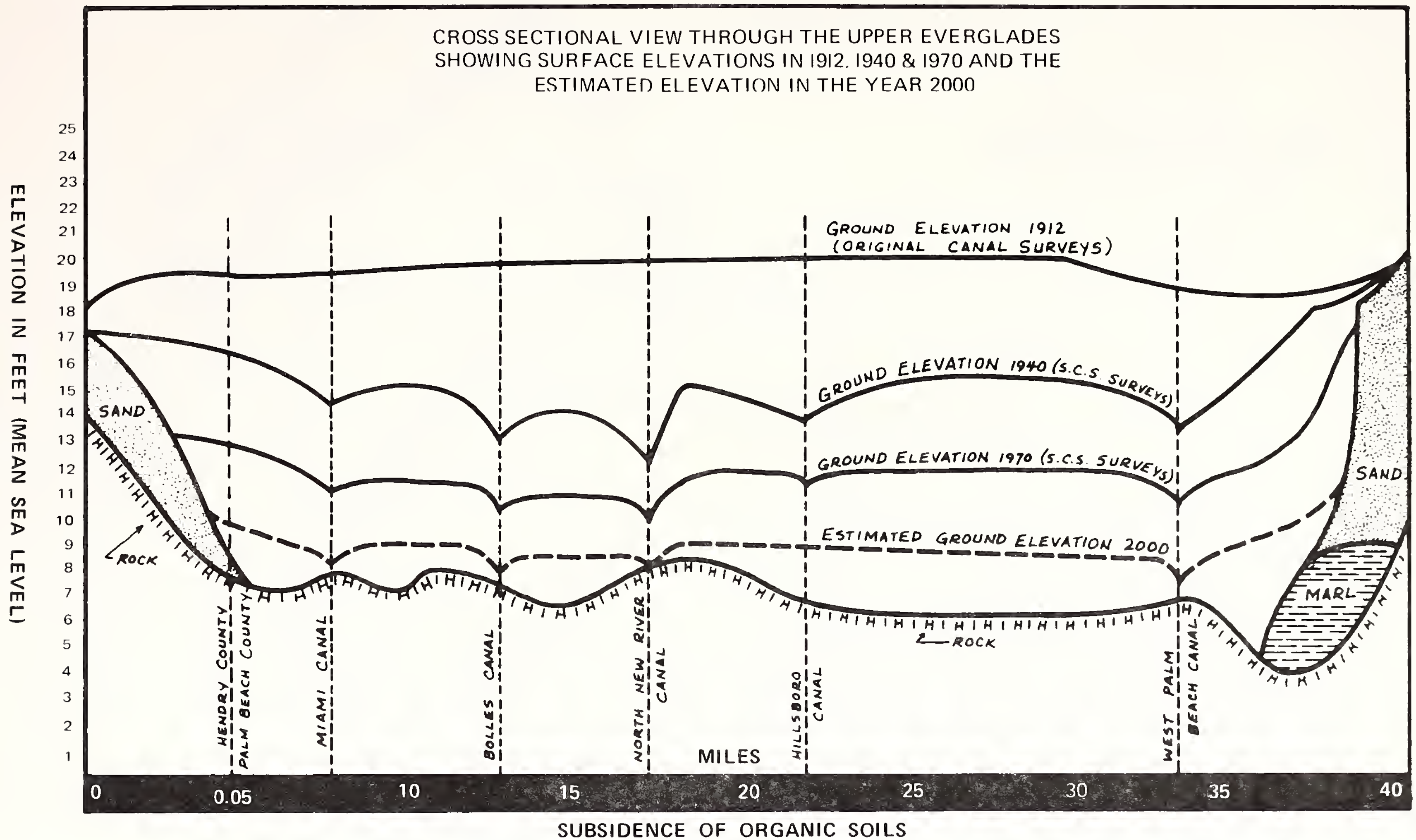
Figure 31



SECONDARY CHANNEL SYSTEM OF THE EVERGLADES
AGRICULTURAL AREA

Source; RELATED WATER CONTROL AREA NO. 12 JUNE 30, 1953

FIGURE 32



SUBSIDENCE OF ORGANIC SOILS IN THE AGRICULTURAL AREA

FIGURE 33

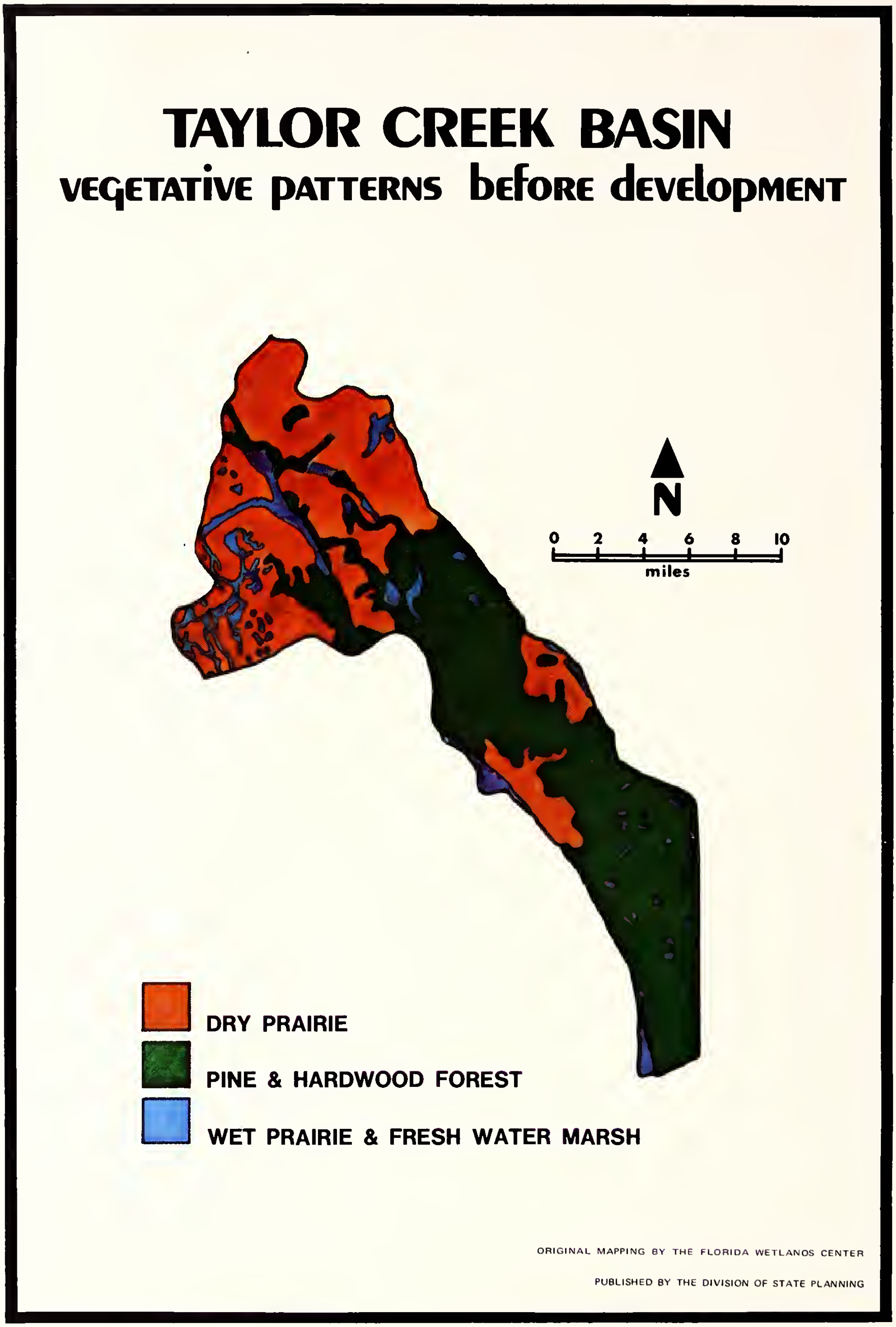

TAYLOR CREEK BASIN
vegetative patterns before development
N
0 2 4 6 8 10
miles
DRY PRAIRIE
PINE & HARDWOOD FOREST
WET PRAIRIE & FRESH WATER MARSH
ORIGINAL MAPPING BY THE FLORIDA WETLANOS CENTER
PUBLISHED BY THE DIVISION OF STATE PLANNING

Figure 34

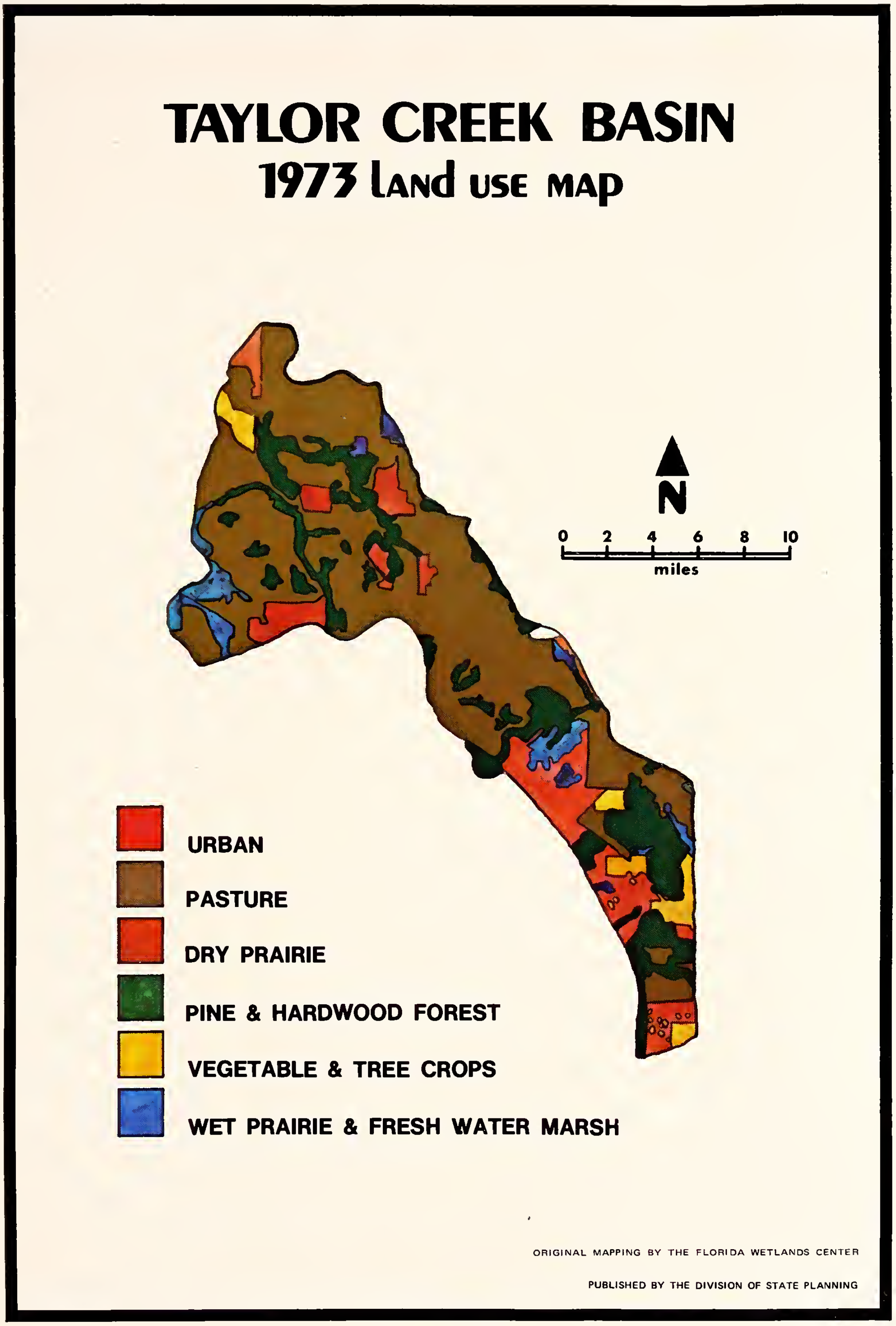
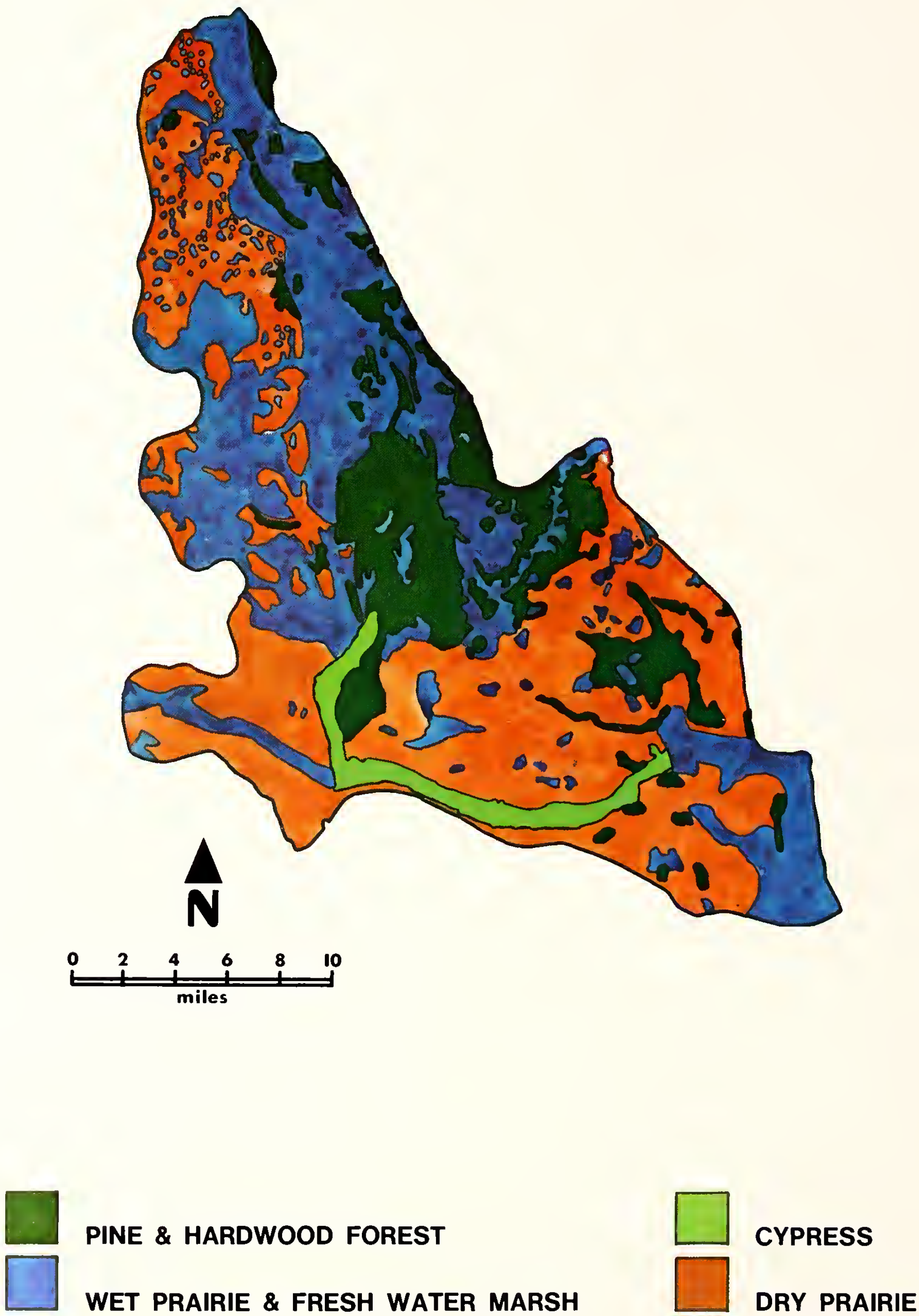

TAYLOR CREEK BASIN
1973 LAND USE MAP
N
0 2 4 6 8 10
miles
URBAN
PASTURE
DRY PRAIRIE
PINE & HARDWOOD FOREST
VEGETABLE & TREE CROPS
WET PRAIRIE & FRESH WATER MARSH
ORIGINAL MAPPING BY THE FLORIDA WETLANDS CENTER
PUBLISHED BY THE DIVISION OF STATE PLANNING

Figure 35

FISHEATING CREEK BASIN
VEGETATIVE PATTERNS BEFORE DEVELOPMENT



ORIGINAL MAPPING BY THE FLORIDA WETLANDS CENTER

PUBLISHED BY THE DIVISION OF STATE PLANNING

Figure 36

FISHEATING CREEK BASIN
1973 LAND USE MAP

ORIGINAL MAPPING BY THE FLORIDA WETLANDS CENTER

PUBLISHED BY THE DIVISION OF STATE PLANNING

Figure 37

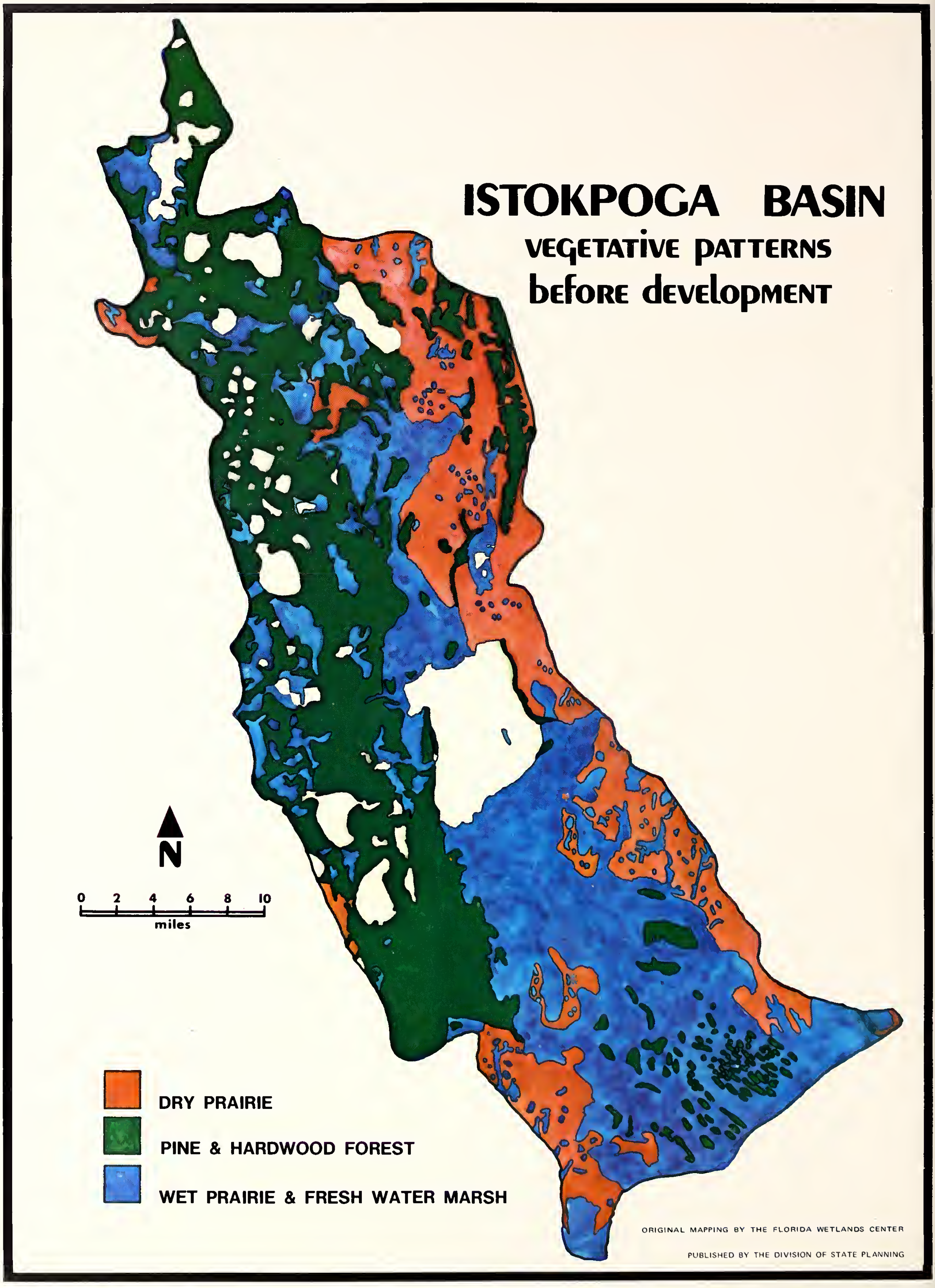
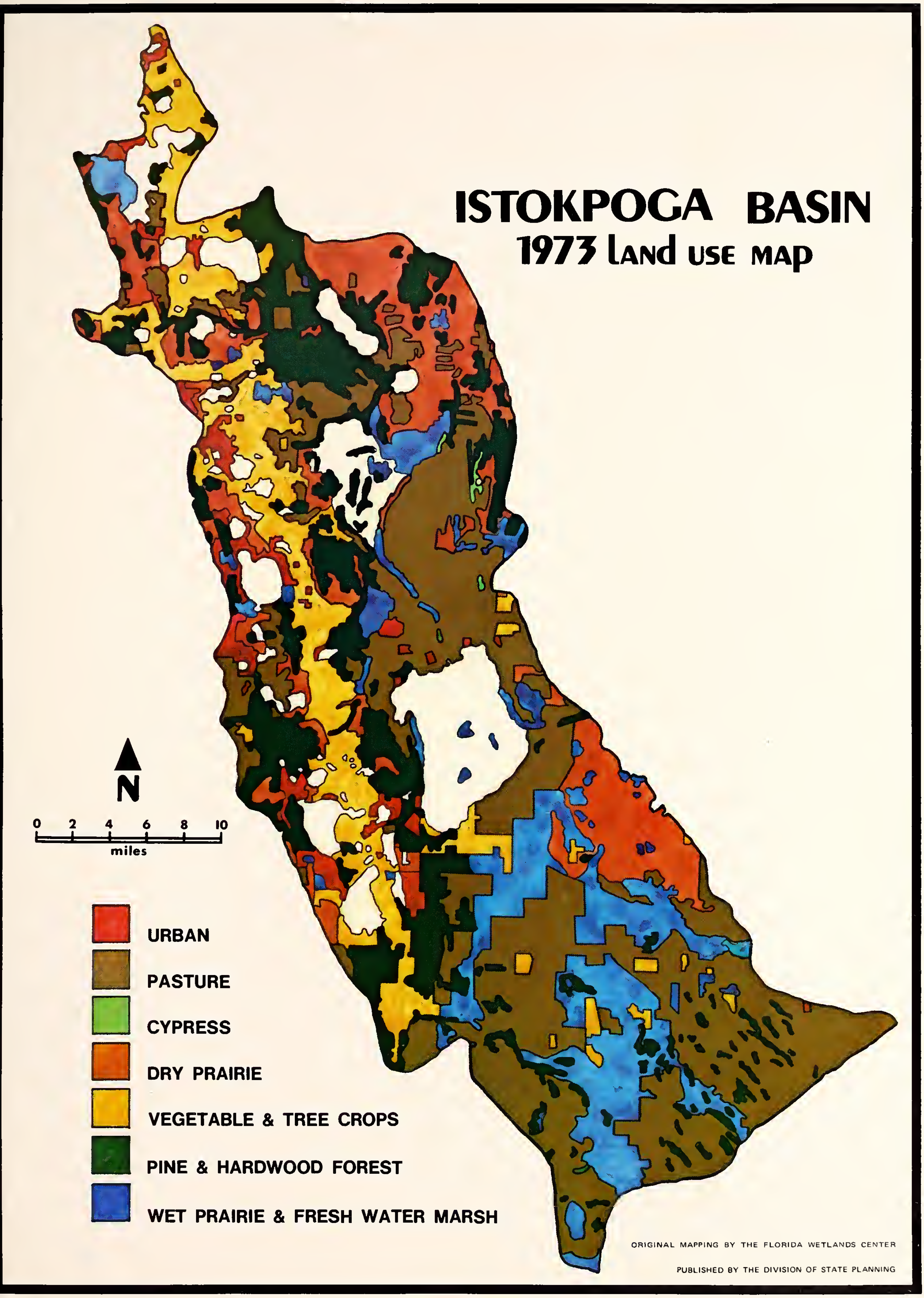
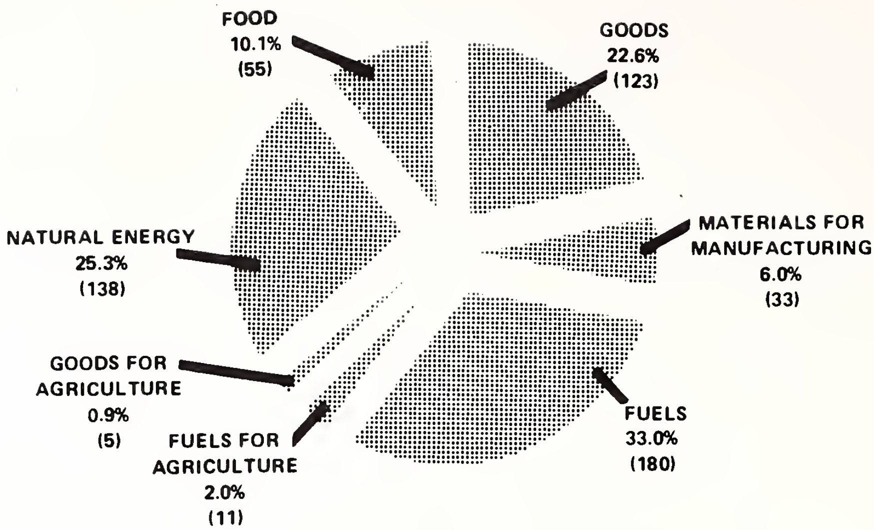

ISTOKPOGA BASIN
vegetative patterns
before development
N
0 2 4 6 8 10
miles
DRY PRAIRIE
PINE & HARDWOOD FOREST
WET PRAIRIE & FRESH WATER MARSH
ORIGINAL MAPPING BY THE FLORIDA WETLANDS CENTER
PUBLISHED BY THE DIVISION OF STATE PLANNING

Figure 38



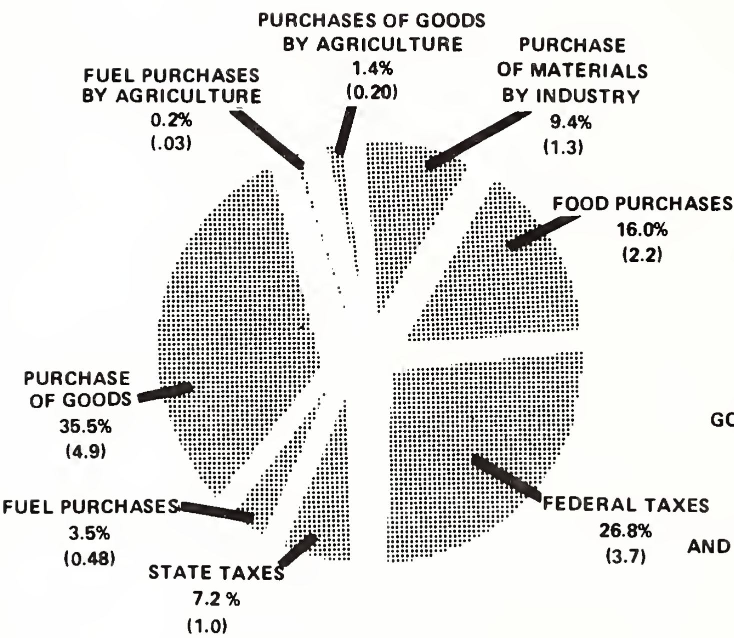
ISTOKPOGA BASIN
1973 LAND USE MAP
N
0 2 4 6 8 10
miles
URBAN
PASTURE
CYPRESS
DRY PRAIRIE
VEGETABLE & TREE CROPS
PINE & HARDWOOD FOREST
WET PRAIRIE & FRESH WATER MARSH
ORIGINAL MAPPING BY THE FLORIDA WETLANDS CENTER
PUBLISHED BY THE DIVISION OF STATE PLANNING

Figure 39



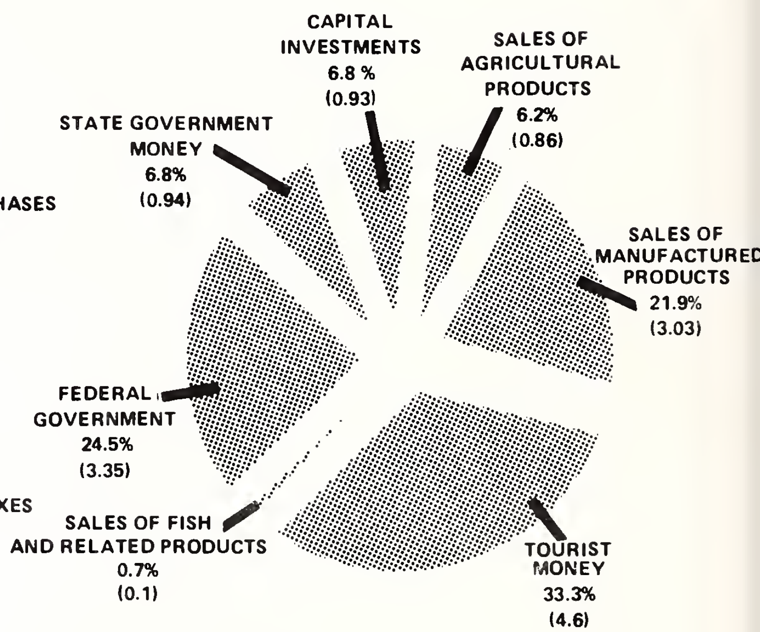
CONTRIBUTIONS TO ENERGY BUDGET
OF SOUTH FLORIDA

(NUMBERS IN PARENTHESES ARE 10^{12} KCAL/YR FFWE;
TOTAL ENERGY INFLOW = $545.X10^{12}$ KCAL/YR FFWE)



PURCHASES OF EXTERNAL ENERGIES
OF SOUTH FLORIDA

(NUMBERS IN PARENTHESES ARE DOLLARS X 10^9;
TOTAL DOLLARS INFLOW = $13.81 X 10^9)



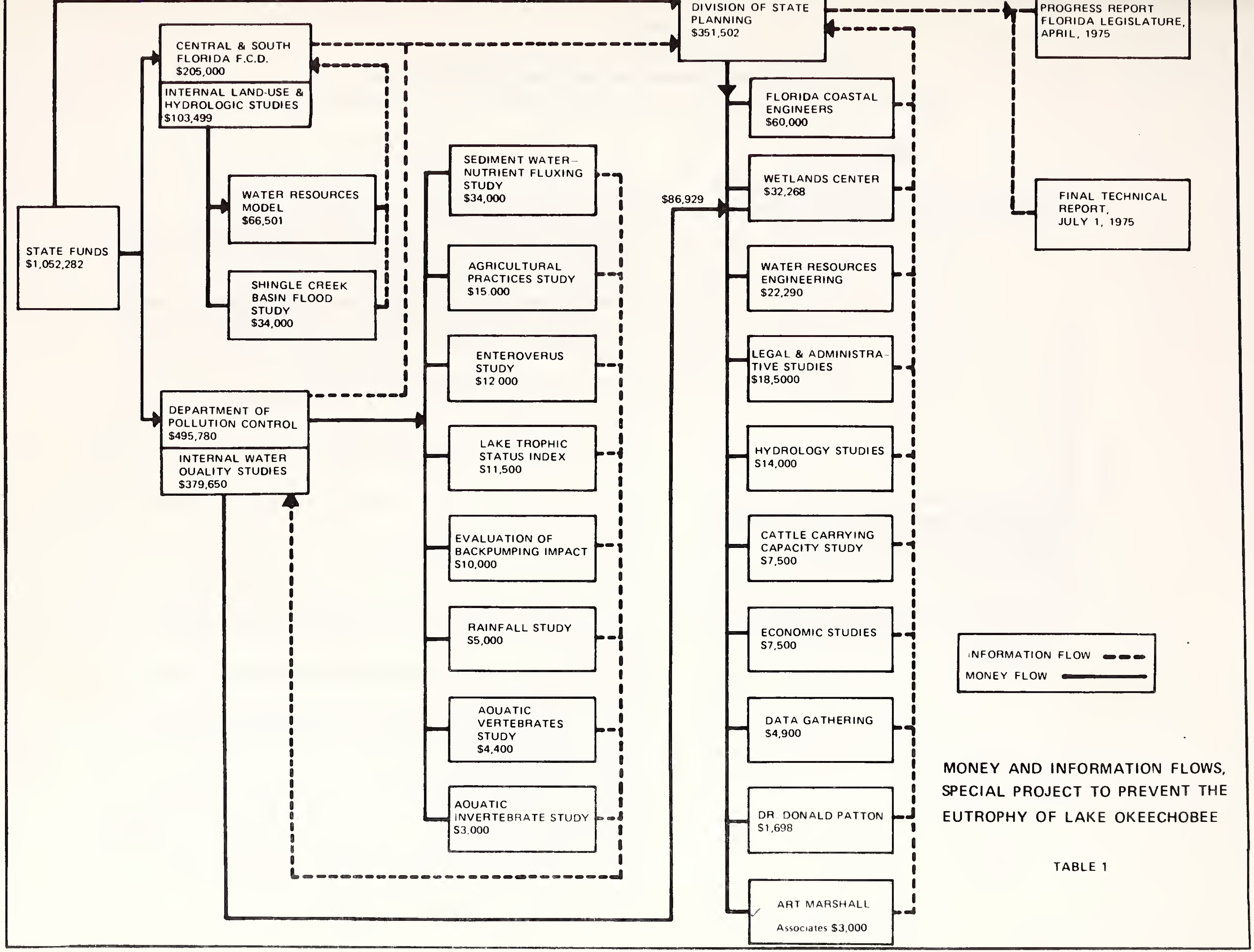
CONTRIBUTIONS TO DOLLAR INCOME
OF SOUTH FLORIDA

(NUMBERS IN PARENTHESES ARE DOLLARS X 10^9;
TOTAL DOLLARS INFLOW = $13.81 X 10^9)

ENERGY AND TREASURY

FIGURE 40

Tables



MONEY AND INFORMATION FLOWS, SPECIAL PROJECT TO PREVENT THE EUTROPHY OF LAKE OKEECHOBEE

TABLE 1

TABLE 2

OBJECTIVES AND SECONDARY OBJECTIVES USED AS CRITERIA FOR EVOLUTION OF THE RESEARCH DESIGN OF THE SPECIAL PROJECT TO PREVENT THE EUTROPHICATION OF LAKE OKEECHOBEE

OBJECTIVES	SECONDARY OBJECTIVES
1. Understand and quantitate, as much as possible, the process of eutrophication as it applies to Lake Okeechobee	a. Quantify nutrient and water inputs to Okeechobee b. Quantify nutrient and water outputs from Okeechobee c. Quantify nutrient storages in Okeechobee d. Research, document and establish the present trophic (eutrophication) status and assimilative capacity (capacity to absorb nutrient inputs over time) of Lake Okeechobee e. Determine acceptable nutrient input levels for long-term water quality f. Identify alternative management strategies and techniques that have potential value to increase assimulative capacity and reduce nutrient inputs g. Model and evaluate management alternatives h. Evolve and evaluate a management plan to prevent the eutrophication of Lake Okeechobee i. Evolve strategies, recommendations, criteria, and administrative approaches for implementation of management plan
2. Understand quantitatively, as much as possible, the inputs to Lake Okeechobee from coupled sub-system drainage basins that relate to eutrophication and water quality management	a. Quantify nutrient and water sources into and within each sub-system drainage basin b. Quantify nutrient and water outputs from each sub-system drainage basin to Lake Okeechobee
3. Understand quantitatively, as much as possible, how alternative management strategies for water quality will effect downstream ecosystem components	a. Quantify nutrient and water flows to downstream components b. Assess ecological consequences, quantitatively as much as possible, of modified flows resulting from various alternative management regimes c. Research land-use, and drainage practices as they relate to nutrient generation and transport d. Identify alternative management strategies and techniques that have potential value for water and nutrient management and conservation within each sub-basin e. Model and evaluate management alternatives f. Evolve a management plan that when implemented, will minimize nutrient outputs from each sub-basin and optimize water flows and ground-water tables for nutrient conservation and ecosystem (including agricultural) productivity g. Evolve strategies, recommendations, criteria, and administrative approaches for implementation of the management plan

TABLE 3

A PROGRESS MATRIX OF OBJECTIVES FOR FINAL REPORT IN OCTOBER 1975

	In Progress	Complete	Being Negotiated
I. DEPARTMENT OF ADMINISTRATION STUDIES			
A. WETLANDS CENTER, UNIVERSITY OF FLORIDA			
1. Agricultural Area Model	X		
2. Kissimmee Marsh Ecosystem Model	X		
3. Agricultural Techniques Model	X		
B. WATER RESOURCES ENGINEERS, INC.			
1. Water Quality Model of the Kissimmee Basin	X		
C. FLORIDA COASTAL ENGINEERS, INC.			
1. Kissimmee River Floodplain Hydrologic Modeling	X		
D. W. HURST & J. KUBAL			
1. Hydrologic Analysis of the Lake Okeechobee Ecosystem	X		
E. B. LESSINGER			
1. Legal and Administrative Aspects of Managing the Lake Okeechobee Basin for Water and Environmental Quality	X		
F. DRS. C. CICCHETTI & D. NICHOLS			
1. Economic Analysis of the Corps of Engineers Cost-Benefit Study of Canalization of the Kissimmee River	X		
2. Economic Cost-Benefit Evaluation of the present Management System and Proposed Alternatives			X
3. Development of Tax Structures to Implement Wise Resource Use and Management			X
G. B. PRUITT			
1. Vegetative Mapping of the Kissimmee River Floodplain Before and After Canalization		X	

			In Progress	Complete	Being Negotiated
H.	ECOIMPACT, INC.				
	1.	Analysis of Cattle Ranching in the Kissimmee River Basin		X	
I.	DEPARTMENT OF ENVIRONMENTAL ENGINEERING SERVICES, UNIVERSITY OF FLORIDA				
	1.	Drainage Density Studies	X		
II.	DEPARTMENT OF POLLUTION CONTROL STUDIES				
A.	WETLANDS CENTER				
	1.	Lake Okeechobee Eutrophication Models	X		
	2.	Lake Okeechobee Hydrology Models	X		
	3.	Kissimmee Upper Chain of Lakes Models	X		
	4.	Lake Okeechobee Regional Models	X		
	5.	Algal Assay Studies	X		
	6.	Enteroviral Studies	X		
	7.	Lake Okeechobee & Kissimmee River Water Quality Studies (Department of Environmental Engineering Sciences, University of Florida	X		
	8.	Survey of Agricultural Practices (IFAS, University of Florida)	X		
	9.	Precipitation Regimes in the Kissimmee-Okeechobee Basin		X	
	10.	Benthic Invertebrate Study		X	
	11.	Aquatic Vertebrate Study		X	
	12.	Trophic Index Study	X		
	13.	Groundwater Study	X		
	14.	Sediment-Nutrient Study		X	
	15.	Various Department of Pollution Control Studies	X		
III.	CENTRAL AND SOUTHERN FLORIDA FLOOD CONTROL STUDIES				
A.	DEPARTMENT OF ENVIRONMENTAL ENGINEERING SCIENCES, UNIVERSITY OF FLORIDA				
	1.	Water Resources Management Studies in the Kissimmee River Basin	X		

		In Progress	Complete	Being Negotiated
B.	REYNOLDS, SMITH AND HILL, INC.			
1.	Inventory of Existing Flooding Conditions in Shingle Creek		X	
C.	STUDIES BEING CONDUCTED BY THE DISTRICT			
1.	Chemical and Biological Investigations of Lake Okeechobee		X	
2.	Prepare Baseline Land-Use Information		X	
3.	Identify and Analyze all Factors Affecting Land-Use Relationships		X	
4.	Expand Hydrologic Data Collection System within the Basin	X		
5.	Develop the Capability to Determine How the Kissimmee-Okeechobee-Everglades Basin Performs Hydrologically under Actual Rainfall by Developing the Relationship Between Rainfall and Surface Water Runoff	X		
6.	Complete and Calibrate a Water Quantity Model for the Kissimmee Basin	X		

TABLE 4

WATER AND NUTRIENT INPUTS
TO LAKE OKEECHOBEE, 1973-74
CENTRAL AND SOUTHERN FLORIDA FLOOD CONTROL DISTRICT
PRELIMINARY DATA

	WATER		NITROGEN		PHOSPHORUS	
	Acre Feet (Thousand)	% of Total	Tons	% of Total	Tons	% of Total
Fisheating Creek	145	5	305	5	24	4
Harney Pond Canal	150	5	481	7	70	13
Indian Prairie Canal	43	1	151	2	17	3
Kissimmee River	1017	34	1923	30	117	21
Nubbin Slough*	204	7	523	8	212	39
Hillsboro-N. New River	178	6	1435	22	40	7
Miami Canal	77	3	621	10	14	2
Precipitation	1014	34	1006	16	54	10

*Drainage from Upper Taylor, Mosquito, Henry, and Lettuce Creeks discharges to Lake at Nubbin Slough.

Source: Baldwin, 1975

TABLE 5

NITROGEN AND PHOSPHORUS LEVELS IN LAKE OKEECHOBEE INFLUENTS

SOURCE	TOTAL NITROGEN (mg/1)		TOTAL PHOSPHORUS (mg/1)		
	1969-70 (a)	1973-74 (b)	1952 (c)	1969-70 (a)	1973-74 (b)
Fisheating Creek	1.4	1.55	0.031	0.068	0.123
Harvey Pond Canal	1.2	2.30		.072	.324
Indian Prairie Canal	1.6	2.61	.121	.082	.298
Kissimmee River	.99	1.39	.012	.078	.084
Taylor Creek	1.6	1.89 (e)	.057	.62	.766 (e)
Nubbin Slough	2.0	1.89 (e)		.36	.766 (e)
Hillsboro Canal	3.8 (f)	5.92 (f)	.017 (d)	.18 (f)	.168 (f)
N. New River Canal	3.8 (f)	5.92 (f)	.028 (d)	.18 (f)	.168 (f)
Miami Canal	1.6	5.95		.036	.133
Precipitation	.90	.73		.056	.038

(a) Joyner, Boyd F., 1974, *Chemical and Biological Conditions of Lake Okeechobee, Florida,* 1969-72, U.S. Geol. Survey, Report Inv. 71. Note: Data from monthly sampling, Jan. 1969 - Jan. 1970.

(b) Central and Southern Florida Flood Control District, Preliminary Data, collected May 1973 - May 1974.

(c) Odum, Howard T., 1953, *Dissolved Phosphorus in Florida Waters,* Fla. Geol. Survey, Report Inv. 9. Note: Data from samples taken - June, 1952 only

(d) Samples collected from Canal in Ag. Area, not at lake outlet.

(e) Sample from Taylor Creek - Nubbin Slough combined lake outlet.

(f) Samples from Hillsboro - North New River combined outlet (s-2).

Source: Baldwin, 1975

TABLE 6

SUMMARY OF MEASUREMENTS ON HILLSBORO CANAL STATIONS

Parameter	Mean	Concentration Low	High
Conductance	1270.000	1190.000	1422.000
pH	7.800	7.800	7.900
Turbidity	3.060	2.800	3.400
Color (color units)	282.000	259.000	320.000
Alkalinity	425.000	383.000	524.000
TOC (mg/)	114.600	100.300	156.000
NO_3 (mg/ as N)	0.068	.065	.080
NH_3 (mg/ as N)	1.640	1.500	1.830
PON (mg/ as N)	.658	.350	.980
SON (mg/ as N)	2.690	2.310	3.640
OP (mg/ as P)	0.227	.108	0.343
TPP (mg/ as P)	.037	.010	.060
TSP (mg/ as P)	0.240	.113	.395
SiO_2 (mg/)	26.300	21.400	40.400
Na (mg/)	140.000	136.000	151.000
K (mg/)	14.780	7.740	17.850
Mg (mg/)	110.000	93.000	134.000
Ca (mg/)	131.000	111.000	177.000
Fe (mg/)	.190	.172	.239
Mn (mg/)	.008	.004	.009
Cl (mg/)	186.000	178.000	193.000
F (mg /)	2.000	1.700	2.220

TABLE 7

SUMMARY OF MEASUREMENTS ON NORTH NEW RIVER CANAL

Parameter	Concentration* Mean	Low	High
Conductance (Hmho/cm)	1101.000	1050.000	1181.000
pH	7.700	7.600	7.800
Turbidity (JTU)	2.600	2.000	4.300
Color	176.000	150.000	192.000
Alkalinity (As $CaCO_3$)	410.000	406.000	414.000
TOC	93.800	92.000	96.000
NO_3 (as N)	0.106	0.015	0.150
NH_3 (as N)	0.728	0.630	0.818
PON (as N)	0.472	0.350	0.560
SON (as N)	2.350	2.240	2.520
OP (as P)	0.055	0.045	0.065
PTP (as P)	0.038	0.010	0.060
STP (as P)	0.095	0.083	0.110
SiO_2 (as P)	16.400	15.400	17.100
Na	84.500	82.000	87.000
K	5.980	5.660	6.370
Mg	94.800	91.000	97.300
Ca	143.000	133.000	145.000
Fe	0.169	0.165	0.173
Mn	0.010	0.007	0.013
Cl	123.000	121.000	125.000
F	1.410	1.230	1.500

*mg/l unless otherwise noted.

TABLE 8

FIELD AND LABORATORY MEASUREMENTS

AT NORTH END OF LAKE OKEECHOBEE

September 6, 1974

	Station				
Parameter	A	B	C	D	E
Secci Disk (cm)	80.000	60.000	70.000	65.000	95.000
Temperature (C)	29.000	28.500	29.000	29.000	29.500
Dis O_2 (mg/l)	3.400	3.400	6.400	6.600	2.400
Depth (m)	2.500	2.250	3.500	3.500	5.500
Sp. Cond. (umho/cm)	190.000	180.000	480.000	495.000	160.000
pH	7.500	7.600	8.400	8.400	7.000
Alkalinity (mg/l as $CaCO_3$)	48.000	42.000	130.000	130.000	24.000
Color (Pt units)	180.000	210.000	115.000	90.000	205.000
F^- (mg/l)	0.070	0.060	0.100	0.090	0.100
TON (mg/l)	1.230	1.280	1.280	1.400	1.340
NH_3-N (mg/l)	0.040	0.040	0.010	0.010	0.050
NO_3–N(mg/l)	0.060	0.020	0.010	0.025	0.030
Ortho P (mg/l)	0.040	0.035	0.025	0.055	0.045
Total P (mg/l)	0.040	0.058	0.053		0.065
TOC	17.000	17.000	20.000	23.000	17.000

TABLE 9

STATISTICAL SUMMARY OF TOTAL PHOSPHORUS DATA, C-38 CANAL

Sampling Station	No. Of Observations	CONCENTRATION (mg/1) Range	Average	Standard Deviation
Above S-65	15	.02 - .06	.033	.008
Below S-65	21	.01 - .06	.027	.010
Above S65A	18	.01 - .07	.029	.014
Below S65A	18	.01 - .09	.034	.020
Above S-65B	19	.01 - .07	.033	.015
Below S-65B	18	.01 - .07	.033	.017
Above S-65C	18	.01 - .06	.032	.013
Below S-65C	17	.01 - .09	.056	.028
Above S-65D	19	.01 - .11	.054	.029
Below S-65D	17	.02 - .12	.068	.023
Above S-65E	20	.02 - .14	.078	.057
Below S-65E	15	.01 - .22	.074	.048

Data Collection Period: 8-30-71 - 8-14-74

TABLE 10

STATISTICAL SUMMARY OF TOTAL NITROGEN DATA, C-38 CANAL

Sampling Station	No. Of Observations	CONCENTRATION (mg/1) Range	Average	Standard Deviation
Above S-65	15	.06 - 2.80	1.31	.57
Below S-65	21	.08 - 3.44	1.27	.67
Above S-65A	18	.12 - 1.99	1.21	.36
Below S-65A	18	.09 - 2.15	1.24	.41
Above S-65B	19	.93 - 2.20	1.30	.40
Below S-65B	18	.21 - 2.57	1.21	.56
Above S-65C	18	.21 - 2.38	1.10	.44
Below S-65C	16	.28 - 2.66	1.30	.63
Above S-65D	19	.32 - 2.18	1.18	.42
Below S-65D	17	.36 - 1.82	1.18	.35
Above S-65E	20	.34 - 3.15	1.25	.54
Below S-65E	15	.38 - 1.80	1.18	.34

Data Collection Period: 3-30-71 - 8-14-74

TABLE 11

KISSIMMEE RIVER VEGETATIVE COMMUNITIES BEFORE AND AFTER CHANNELIZATION

Vegetative Community	Acreage	% Of Total Acreage
1. Pasture	5,991	11.16
a) Improved	(901)	(1.37)
b) Unimproved	(5,090)	(9.79)
2. Marshland	40,600	78.16
3. Shrubland	555	1.06
4. Open Water and Ruderal	5,750	9.14

Vegetative Community	Acreage	% Of Total Acreage	% (+) Increase % (–) Decrease
1. Pasture	28,180	54.24	+379
a) Improved	(15,400)	(29.64)	(+1,610)
b) Unimproved	(9,020)	(17.36)	(+151)
c) Shrubby	(3,760)	(7.23)	(+151)
2. Marshland	8,840	17.02	–69.6
3. Shrubland	2,170	4.17	+291
4. Open Water and Ruderal	5,380	10,35	+13.3
5. Spoil Banks (entire)	(8,680)	(16.71)	
a) in pasture	(1,300)*	(2.51)	
b) unused	7,380	14.20	
	51,950	99.98	

TABLE 12

IRRIGATION BY WATER SOURCE IN FISHEATING CREEK

1968 Irrigation Water Uses

SCS Planning Unit	Total Acres	Total Surface Water	Citrus 1000 Ac.	Citrus 1000 Ac.	Other Crops 1000 Ac.	Other Crops 1000 Ac-Ft	Improved Pasture 1000 Ac	Improved Pasture 1000 Ac-Ft
31	53.2	0.2	0.1	0.2	--	--	2.9	7.5
.44	64.6	0.0	--	--	--	--	3,4	8.8
45	75.1	0.2	1.2	1.8	--	--	1.5	3.9
45	102.4	0.5	2.5	3.8	1.0	2.6	1.1	2.9

1980 Irrigation Water Needs

SCS Planning Unit	Total Acres	Total Surface Water	Citrus 1000 Ac.	Citrus 1000 Ac-Ft	Other Crops 1000 Ac.	Other Crops 1000 Ac-Ft	Improved Pasture 1000 Ac.	Improved Pasture 1000 Ac-Ft
31	53.2	0.2	0.2	0.3	2.1	I.5	5.0	13.0
.44	64.6	0.0	0.2	0.3	1.8	1.3	4.8	12.5
45	75.I	0.2	1.3	2.0	0.1	0.1	3.0	7.8
45	102.4	0.5	2.7	4.2	1.5	3.9	3.2	8.3

Irrigation by Water Source 1968

SCS Planning Unit	Total Acres	Total Surface Water	Surface 1000 Ac.	Surface 1000 Ac-Ft	Subsurface 1000 Ac.	Subsurface 1000 Ac-Ft
31	53.2	0.2	--	--	2.8	7.5
.44	64.6	0.0	--	--	3.4	8.8
45	75.1	0.2	--	--	2.7	5.6
45	102.4	0.5	3.3	7.0	1.2	2.4

Source: U.S.D.A., Soil Conservation Services, River Basin Investigation *Report for Kissimmee Everglades Area,* Florida, Appendix, 1973

Appendices

APPENDIX A

FROM THE GOVERNOR'S CONFERENCE ON WATER MANAGEMENT IN SOUTH FLORIDA

There is a water crisis in South Florida today. This crisis has long-range and short-range aspects. Every major water area in the South Florida basin, Everglades National Park, the conservation areas, Lake Okeechobee and the Kissimmee Valley is steadily deteriorating in quality from a variety of polluting sources that are detailed below. The quantity of water, though potentially adequate for today's demand, cannot now be managed effectively over wet/dry cycles to assure a minimum adequate water supply in extended drought periods.

WATER SUPPLY - QUANTITY

To initiate an action program to solve problems in the area of water quantity, a careful assessment must be made of water demands linked to projected growth. For an adequate long-range water supply, the State must have an enforceable comprehensive land and water use plan. This plan must be developed immediately. It must be designed to limit increases in population and machines, with their attendant demands on the water supply, to a level that will insure a quality environment. *Such a management plan would include, as its first objective, a complete inventory and assessment of long-range water resources. The controling factor in this water resource assessment should be the water supply that can be anticipated in times of shortest supply.* A result of this planning effort would be a water budget system based on available resources. This system would serve as a limitation on allowable population increases.

WATER SUPPLY - QUALITY

Water quality is a far graver problem in the long run than is water quantity. The quality of the water in the South Florida water basin is deteriorating. This deterioration stems from the introduction into the basin of pesticides, herbicides, animal and industrial wastes, heavy metals, salt water, sewage and heated waters. Channelization has contributed substantially to the process of deterioration. Water quality in the basin may be restored and maintained by:

1. Zoning or acquiring the flood plains in the basin.

2. Reflooding the Kissimmee marshes.

3. Initiating a comprehensive treatment program to treat pollutants at the source before they enter the water system. (This would necessitate initiation of treatment procedures in agricultural areas and up-grading existing procedures in urban areas.)

4. Phasing out back pumping into Lake Okeechobee or requiring effective treatment at the source before back pumping.

5. Research and funding which should begin immediately to study what to do about recycling water and sewage effluents and solid waste disposal.

LAND RECLAMATION

There should be no further draining of wetlands for any purpose. As an initial step in controlling the drainage of wetlands, it is recommended that Chapter 298 of the Florida Statutes (Soil drainage district law - 1913) be repealed. Wetlands are the most biologically productive of all lands. The need to preserve them stems from their value for recreation, water storage, aquatic productivity, nutrient removal and for aquifer recharge. A program should be initiated to reflood the marshes of the Kissimmee Valley. *Agricultural lands and marshes not presently in production below Lake Okeechobee should also be reflooded.* The initial efforts should be pilot projects that can provide a clearer assessment of the benefits and techniques of reflooding. It is crucial to reverse the process of the steady loss of organic soils. Reflooding is the primary method for accomplishing this objective. This program should include the acquisition and consolidation of lands by the State in selected areas north of Conservation Area Three and/or near Conservation Area Two as a major pilot program. Its purpose shall be to determine the effect of controlling water levels, filtering pollutants and recycling wastes to build up organic soils. Muck conservation programs should be coordinated and pursued immediately by the Central and Southern Florida Flood Control District and Trustees of the Internal Improvement Trust Fund. Even if mucklands are not used for agriculture, their preservation and restoration are necessary to maintain the ecological balance of the South Florida basin. Reestablishment of sawgrass may be the best solution to replenishment of the mucklands. However, other approaches should be considered on an experimental basis, including the use of organic material such as sewage sludge.
(A minority position held that limited drainage of wetlands to serve a clear public interest, under strict controls, may be justified.)

POPULATION

There is a limit to the number of people which the South Florida basin can support and at the same time maintain a quality environment. The State and appropriate regional agencies must develop a comprehensive land and water use plan with enforcement machinery to limit population. This is especially crucial in the South Florida region. The population level must be one that can be supported by the available natural resources, especially water, in order to sustain a quality environment. A State comprehensive land and water use plan would include an assessment of the quality and quantity of these resources. Moreover, it would set density controls on further development by regions and sub-regions.

GROUND WATER

Localized ground water problems are common in South Florida, but they are especially severe in South Dade County and in portions of Collier and Lee Counties. Ground water contaminations and depletion problems include salt water intrusion, uncontrolled drilling of wells, drainage well pollution, inefficient waste water disposal systems, septic tanks and sanitary land fill. Solutions to ground water problems include:

1. A State Drilling Code requiring licensing of all wells and well drillers.

2. Purchase or zoning of lands to protect recharge areas.

3. Plugging of abandoned artesian wells.

4. Installation of secondary controls in major canals to hold higher heads of water.

5. Construction of additional salt water intrusion control facilities, except on natural rivers, according to a salinity control line established along the entire South Florida coast.

6. Elimination of the disposal of improperly treated waste waters.

7. Consideration of all artificial recharge methods which do not impair the quality of the ground water.

8. Consideration, after study, of filling in certain canals in the South Dade County area to improve ground water quality.

9. Prohibition of deep cuts made into the aquifer at the salt water line which cannot be adequately controlled by salinity barriers to prevent salt water intrusion.

Water quality, quantity and development controls described elsewhere in this report will also improve ground water conditions in the basin.

GEOGRAPHIC CONSIDERATIONS

The South Florida water resources can only be understood by considering the entire area. The area begins with the Kissimmee Valley chain of lakes in the north, extends southward through Lake Okeechobee, the Everglades (including the Big Cypress) and encompasses all coastal and estuarine areas. Any significant change in water quality or quantity in one part of the total area must be considered in light of its effects on the rest of the system.

A. The Kissimmee Valley

Pollutants entering the Kissimmee Valley have cumulative adverse effects on water quality in the Kissimmee chain of lakes and in Lake Okeechobee. *The Kissimmee lakes and marshes should be restored to their historic conditions and levels to the greatest extent possible in order to improve the quality of the water entering Lake Okeechobee.* Action should be taken to restore fish resources and wildlife habitats. Contamination by pastured livestock must be reduced. Techniques should be investigated to increase restoration of selective areas to their natural condition by use of advanced waste disposal and composting materials.

B. Lake Okeechobee

Recognizing that Lake Okeechobee is the hub of water quantity and quality in South Florida, the most important and overriding consideration should be not only to maintain the present quality of the lake but also to improve it. Specific consideration should be given to assure that all water inputs into Lake Okeechobee are of high quality. *Two primary inputs which could improve the quality of water are (1) reflooding of the Kissimmee Valley flood plain and (2) assuring that only high quality water is back pumped into the lake.* We should consider the following ways, in addition, to assure high quality lake water:

1. An appropriate monitoring and enforcement program.

2. Allowing a maximum high water level mark of seventeen and one-half feet. Higher controlled elevations will not be considered unless it can be clearly shown that such elevation would have no adverse effect on the environment of Lake Okeechobee, its water quality or the ecosystem of South Florida.

3. Allowing no cattle or agricultural activities inside the diked area of the lake and immediate cancellation of all agricultural and mineral leases inside the diked area.

4. Ways should be sought to replace chemical control of aquatic weeds with alternate methods which are not harmful to the Lake Okeechobee ecosystem.

5. Nutrient removal by periodic commercial harvesting of the lake's extensive fish population.

6. Nutrient removal by harvesting of aquatic weeds.

C. Everglades Outside the Park

Everything possible should be done to retain and enhance those areas in their natural condition. There is a need for continuous monitoring and control of these water resources since they provide supplies to the total South Florida area, including urban areas. A specific objective should be to maintain and restore the sawgrass. Present intrusion of non-public interests should be removed from Conservation Areas 1, 2 and 3 and all privately owned lands in said areas be purchased. It is important that the Big Cypress area be purchased to the greatest extent possible and that land use controls be established immediately in the Big Cypress to control development and to preserve this area for the public benefit. Other potentially valuable areas that need protection are the Shark River Slough, its head water areas and the general area near Canal C-111.

D. Everglades National Park

We should attempt to maintain the water quality and quantity of the Park adequate for the purpose for which the Park was created. Where it is deemed advisable, exotic

plants and animals should be controlled in the Park and throughout the Everglades area.

SHORT TERM PROBLEMS

An inter-agency committee should be established immediately to consider short term water management problems. The purpose of this committee shall be to develop an ecologically sound body of guidelines and policy to be followed in the resolution of short term problems of the region. There should be an educational program to alert the public to the possibilities and consequences of water shortage.

A. Fire Prevention and Control

Through programmed burning maintain an approximation of the original fire regime of the area. There should be controlled burning to protect the natural plant and animal systems and to prevent undesirable build-up of plant materials. Man should be excluded from critical areas in times of drought. Fire laws should be strictly enforced.

B. Intrusion of Salt Water

To prevent the intrusion of salt water within the coastal areas, the fresh water head should be maintained as high as feasible. When a water shortage is anticipated, restriction of water use will be necessary in order to maintain this head of fresh water during the drought. Temporary dams should be built on canals, when necessary, with an established emergency system of permitting to allow construction of such dams. During droughts, navigation service should be restricted in order to reduce loss of fresh water. Canals should not be constructed which would allow salt water intrusion inland of the salt water line. Appropriate local laws should be established and enforced.

C. Establishment of Water Priorities

Since there is competition for water by agriculture, urban areas, conservation areas, estuaries and the Everglades National Park it is recommended that the total water supply be considered a common resource. Survival of the entire South Florida ecosystem, without sacrificing any segment, should be the prime consideration. Maintaining the head of fresh water should be given first priority. The inter-agency committee should propose priorities in its over-all plan.

D. Regulation of Water Use

A model water use priority ordinance should be developed for use by all affected areas, establishing a series of consumptive controls based on the degree of water shortage.

E. Desirability of Cloud Seeding

Cloud seeding is not considered a short term solution. There was a division of opinions on the desirability of cloud seeding primarily due to a lack of knowledge, especially as to the possible adverse environmental effects. An opinion is that cloud seeding may be more effective in producing a water supply during the wet season to mitigate low water supplies during the dry season. However, further research is recommended.

F. Schedules of Water Levels in Lake Okeechobee and the Conservation Areas

The inter-agency committee should develop and maintain close coordination between the U.S. Army Corps of Engineers, the Central and Southern Florida Flood Control District, the Florida Game and Fresh Water Fish Commission, the U.S. Department of the Interior and where appropriate, the Florida Department of Natural Resources. The purpose should be to establish water levels in Lake Okeechobee and the Conservation Areas as well as to establish flexible regulation and delivery schedules for all water needs in South Florida.

MANAGING AGENCY FOR THE SOUTH FLORIDA REGION

Water management should be coordinated at the federal, state and regional levels, with the leadership role clearly being taken by the State of Florida. At the state level there must be an agency or board that has all power necessary to develop and ensure implementation of a comprehensive land and water use plan for the state. The agency or board, whichever it may be, should report to the Governor.

A regional board for South Florida shall be established. The regional board shall be composed of nine (9) members appointed by the Governor. Three year staggered terms shall be used. The board shall represent the diverse interests in the region. It should hold periodic public hearings in its region for the purpose of receiving input from the public. It shall develop and implement a regional comprehensive land and water use plan in accordance with the State plan. The development of this regional plan should commence at once with the proper funding and legislative authority, even in the absence of an adequate statewide plan. In the development of these long range plans, procedures should be adopted which allow and encourage full public participation and input.

The geographical boundary of the South Florida regional land and water management agency shall be the Kissimmee River Basin, the Okeechobee Basin, the Everglades and the Big Cypress Watershed, including all adjacent coastal and estuarine areas. The regional land and water management agency shall be responsible for managing water quality and quantity for the long term benefit of the environment of the region and the State. The agency shall be responsible for establishing policy and guidelines for such activities as drainage,water use, well drilling, land use, estuary protection, watershed management, flood control and soil conservation.

The regional agency shall have all powers necessary to develop and implement the regional land and water use plan including, but not limited to, taxing powers, eminent domain, police powers such as intervention to protect the environment, permits for drainage districts and canals,

subpoena and investigative powers and research properly coordinated with other agencies. A law providing for public condemnation of lands for environmental protection is essential to the implementation of the objectives herein presented.

The regional agency shall be required by the State to relate to and coordinate with duly constituted State and regional organizations operating in other functional areas.

Finally, the conference recognizes that present funding for environmental protection must be greatly enlarged to accomplish the common goal of protecting the economic and environmental values of the State.

APPENDIX B

LAKE OKEECHOBEE - KISSIMMEE BASIN WATER QUALITY INFORMATION

CENTRAL AND SOUTHERN FLORIDA FLOOD CONTROL DISTRICT

SUMMARY

A nutrient (nitrogen and phosphorus) loading study on Lake Okeechobee for the period January 1969-January 1970 was conducted by the U.S. Geological Survey. A similar nutrient loading study was conducted by the District for the period May 1973-May 1974. Lake Okeechobee water quality data collected in connection with these two studies show that in the span of five years covered there has been no basic change in the Lake's water chemistry.

Both nutrient loading studies showed approximately the same thing with respect to the principal sources of nutrient loads to the Lake. Rainfall is a substantial contributor of both inflow (35%-40%) and nutrients (about 20%) to the Lake. Removing rainfall from consideration because its input is "uncontrollable", the District's study shows that the Kissimmee River with 57% of the inflow contributes 23% of the phosphorus load to the Lake, whereas the Taylor Creek/Nubbin Slough area with 11% of the inflow contributes 43% of the phosphorus load. On the same basis the Kissimmee River contributes 36% of the nitrogen load, while the Everglades Agricultural Area with 14% of the inflow contributes 38% of the nitrogen load.

Since water quality management is a function of the amount of water to be handled, and the land area on which that water is generated, it appears clear that any such management effort should be first applied to those areas where the unit nutrient load per unit of water is the greatest. Such a "nutrient loading index" can be applied to the various areas tributary to the Lake. For phosphorus loading the index is 3.9 for Taylor Creek/Nubbin Slough in comparison with 0.4 for the Kissimmee River and 0.6 for Fisheating Creek. For nitrogen loading the indices are 2.7 for the Agricultural Area and 0.6 for both the Kissimmee River and Fisheating Creek.

In the Kissimmee Basin the District's water quality data and that of the U.S. Geological Survey indicate that the water entering the north end of C-38 is of good quality. Man's activities in the Upper Basin at present have no adverse impact on Lake Okeechobee. Although nitrogen concentrations are nearly uniform throughout the length of C-38, phosphorus concentrations increase from north to south. It is estimated that in a normal year about 55% of the total phosphorus load entering the Lake would come from the 255 sq. mile area tributary to the lower end of C-38, with about 15% of the inflow from the Kissimmee Basin. The "nutrient loading index" for this area, for phosphorus loading, would be 3.5.

District studies in one of the watersheds (Chandler Slough) tributary to the lower end of C-38 indicate that a segment of undisturbed marsh at the lower end of the watershed is effective in reducing the phosphorus concentrations. Average retention time for water flowing through this 3.5 mile long, 1,000 acre, marsh was estimated to be 3 days. Phosphorus concentrations were reduced 25%-55%, with flow rates varying from 50 cfs to 400 cfs.

These studies identify three specific areas to which immediate and affirmative water quality management attention should, and can, be directed:

1. Taylor Creek/Nubbin Slough

2. That portion of the Everglades Agricultural Area tributary to Pumping Stations 2 and 3

3. The area tributary to C-38 downstream of Structure 65C

LAKE OKEECHOBEE - WATER CHEMISTRY

In January 1969, the U.S. Geological Survey under its cooperative program with the District initiated a study of the enrichment characteristics of Lake Okeechobee. As a part of that study a water and nutrient budget for the Lake was calculated for the period January 1969 through January 1970. Upon the termination of that study the District continued and intensified the water quality sampling program in the Lake and at the inflow points to the Lake. A similar water and nutrient budget for the Lake was calculated by the District for the period May 1973-May 1974. The total period spanned from the initiation of the U.S. Geological Survey nutrient budget study and the cut-off point of the first year of the District's nutrient budget study is a little over 5 years. Nutrient loads to the Lake were computed in both studies.

Total inflow to the Lake for the 13-month period of the U.S. Geological Survey study was above the long-term average; being approximately 8.86 million acre feet. For the 12-month period of the District study the total inflow was about 75% of the long-term average; or approximately 3.00 million acre feet. The following table lists the normal inflows from each major tributary, the calculated inflows during each study period, and the percent of normal inflow (adjusted approximately for the difference in length of the study periods).

Inflow Point	Normal Inflow (MAF)	1969-70 Inflow (MAF)	1969-70 % Normal	1973 74 Inflow (MAF)	1973 74 % Normal
Kissimmee River	1 58	3 47	210%	1 02	65%
Taylor Creek/ Nubbin Slough	07	.37	520%	20	286%
C-40 and C-41	.19	41	210%	19	100%
S-2 and S-3	.25	04	25%	26	100%
Fisheating Creek	.19	64	330%	14	74%
Rainfall	1.75	3.57	200%	1 01	58%
Other Sources	0-	.36	0	18	0
TOTAL	4.03	8 86	220%	3 00	74

The three sets of inflow values listed above reveal several features of importance. One of these is that volumetrically the input from direct rainfall on the Lake closely tracks that of inflow from the Kissimmee River. Another is that the long-term average inflow on Taylor Creek (dating back to 1955) may no longer be a valid indicator of present flow conditions in that watershed.

This table also shows that the 1973-74 data represent a reasonable approximation of the "normal" water inflow regime of Lake Okeechobee. It is presented in order to provide a framework for the comparisons made in the following table, which lists for both study periods average nutrient concentrations of the inflow water at each of the inflow locations, and the percentages of total water and nutrient load contributed to each location.

Both sets of data show certain of the same things:

1. Nutrient concentrations of the Kissimmee River inflow are less than the concentrations of any other inflow, except precipitation.

2. The percentage of Fisheating Creek and Kissimmee River's contributions to total nutrient loading is closely related to their water flow contributions.

3. The contribution of phosphorus from Taylor Creek/Nubbin Slough is disproportionately high in relation to its flow contribution;being equal to or greater than that from the Kissimmee River with only 10%-20% of its flow.

4. The contribution of nitrogen from the Agricultural Area (S-2 and S-3) is disproportionately high in relation to its flow contribution; being about equal to that of the Kissimmee River with only about 25% of its flow (1973-74 data).

5. The Taylor Creek/Nubbin Slough and S-2/S-3 data, together with that from C-40/C-41, indicate a definite relationship between type of agricultural land use, soil type, and character of the nutrient loading. The highest phosphorus concentrations and loadings are found in an area used intensively for dairy-farming, and next highest in an area (C-40/C-41) largely devoted to pasture. The highest nitrogen concentrations and loadings derive from a muckland area devoted to row crops and cane.

6. There has been no basic change in the chemical water quality of the Lake in the five-year period, nor has there been any material change in the relative significance of the nutrient loading values from the various contributing sources, with the possible exception of the phosphorus loading from the Indian Prairie area. (C-40/C-41).

7. Water inputs to the Lake from direct precipitation are roughly equivalent to inputs from the Kissimmee River, and total nutrient loads from that source are approximately half of that from the Kissimmee River.

Although the nutrient loads entering the Lake from direct rainfall on the Lake are substantial and contribute to its enrichment status, this input is uncontrollable. Therefore, it will be useful to put the water and nutrient loading data from immediately preceding table into a form which is related to potentially "controllable" inflows by excluding direct precipitation from the calculations. The following table presents the 1973-74 data in this form; this data being more representative of an "average" or "normal" condition than that for 1960-70. (The value for "other sources" is also excluded in this table.)

Inflow Point	% of Total "Controllable" Inflow	% of "Controllable" Nutrient Loading	
Kissimmee River	57%	36%	23%
Taylor Creek/ Nubbin Slough	11%	9%	43%
C-40 and C-41	10%	12%	18%
S-2 and S-3	14%	38%	11%
Fisheating Creek	8%	5%	5%

The above table can be used to provide some rough measure of cost-effectiveness if it is assumed that: (a) the cost of reducing the nutrient load is directly proportional to the volume of water to be handled, and (b) the cost of nutrient removal or control in each tributary area is the same. The percentages in the above tabulation can be considered as units of water, nitrogen load and phosphorus load respectively. Dividing the nutrient load units by the water units produces a number representing the unit of nutrient load per unit of water. With the assumptions given above, the larger the number so produced, the more cost-effective will be the nutrient removal measures. The following tabulates these indices:

Inflow Point	N Loading Indices	Inflow Point	P Loading Indices
Kissimmee River	0.63	Kissimmee River	0.40
Fisheating Creek	0.63	Fisheating Creek	0.63
Taylor Creek/ Nubbin Slough	0.82	S-2 and S-3	0.79
C-40 and C-41	1.20	C-40 and C-41	1.80
S-2 and S-3	2.71	Taylor Creek/ Nubbin Slough	3.91

Although the first assumption made above is valid, the second one is not necessarily so. Therefore, the table does not necessarily represent a set of cost-effectiveness indices. However, it does serve as a strong indicator of where nutrient reduction measures should be taken which would be most productive in terms of reducing nutrient load impact on the Lake.

It is clear that in terms of nitrogen load attention must be focused on the S-2, S-3 area, and in terms of phosphorus load the Taylor Creek/Nubbin Slough area must be addressed.

These indices serve to provide a better perspective of the relative importance of nutrient loads entering the Lakes from various sources, in consideration of the potential manageability of those loads as expressed by the volume of water requiring handling. In these terms Fisheating Creek and the Kissimmee River are relatively unimportant whereas Taylor Creek/Nubbin Slough and the northwesterly portion of the Agricultural Area are relatively more important.

KISSIMMEE BASIN - WATER CHEMISTRY

Intensive water quality sampling in C-38 initiated by the U.S. Geological Survey in 1971 under its cooperative program with the District, and expanded under the District's own program in C-38, in the tributaries to C-38 and in the lakes of the Upper Basin clearly indicates that the water leaving Lake Kissimmee and entering C-38 is of good quality. These data irrefutably show the picture of pollutants from Central Florida "sluicing" down C-38 to Lake Okeechobee which was painted for the Governor and Cabinet as recently as December 1972 is grossly inaccurate. The lakes of the Upper Basin, and in particular Lake Tohopekaliga, are at present assimilating these pollutants. This is not to say that the nutrient loads entering at the north end of Lake Tohopekaliga are not adversely impacting that lake. It is to say, however, that the impact of those loads is being absorbed quite probably by the time water leaves Lake Tohopekaliga and most certainly by the time it enters C-38.

The following tabulates average nitrogen and phosphorus concentrations in C-38, for various time periods, observed by both the U.S. Geological Survey and the District:

	Average N concentration Annual (mg/1)			Average P concentration Wet Season (mg/1)			
Location	1971-72	1972-73	1973-74	1971	1972	1973	1974
S-65	2 10	1.53	1.27	-0-	0.017	0.033	0 032
S 65A	1.65	1.20	1.14	0.069	0.021	0.030	0.042
S-658	1 50	1.14	1.09	0.048	0.023	0.042	0 042
S-65C	1 60	1.08	1.06	0.055	0.045	0.050	0.053
S-65D	1 55	1.15	1.03	0 100	0.063	0.061	0.069
S-65E	1 60	1 09	1.14	0.187	0.082	0.090	0.088

These data show a relatively uniform distribution for nitrogen concentrations along the length of C-38. Less than 10% of the total nitrogen is in the inorganic form, the form most readily available for biological uptake. The data also show that phosphorus concentrations increase rather dramatically in the reach of C-38 downstream of Structure S-65C.

For study purposes the lower Kissimmee Valley has been divided into planning units, based on watershed boundaries adapted from SCS. There are five such units (13-17) between Structure 65 at the Lake Kissimmee Outlet and Structure 65E, which discharges Kissimmee Basin outflow to Lake Okeechobee. Planning unit 18 is located downstream of Structure 65E.

An index of drainage capability, called the "drainage density", has been developed for and applied to various planning units and watersheds in the lower valley. This index is simply the total length of defined waterways (both natural and man-made) within the watershed divided by the watershed area. No attempt is made, in developing this index, to distinguish between natural and man-made channels; both are given the same weight. The following table lists, from north to south, the drainage density index for each of the planning units upstream of S-65E and the average phosphorus concentrations in the reach of C-38 to which the planning unit is tributary:

Planning Unit	Area (sq. mi.)	Drainage Density (mi/sq. mi.)	Tributary Pool	Average P Concentration (mg/1)
13	146	3 42	S-65A	0 025
14	225	2.92	S-658	0 037
15	68	4.92	S-65C	0 038
16	161	5.79	S-65D	0 059
17	59	5.68	S 65C	0 082

A further indication of the relationship between drainage density (degree of watershed drainage) and phosphorus concentrations is revealed in the following table. This table lists average phosphorus concentrations in the outflow water from selected watersheds together with the drainage density index for those watersheds:

Watershed	Area (sq. Mi.)	Located Within Planning Unit	Drainage Density (mi/sq mi.)	Average P Concentration (mg/1)
Ice Cream Slough	60.3	13	1 49	0.02
Pine Island and Seven Mile Slough	98.9	14	2 92	0 03
Chandler Slough	49.0	16	9.23	0.33

Drainage effectiveness, of which drainage density is a rough measure, is, of course, not the only factor which affects phosphorus loading. The Lake Okeechobee loading data presented earlier shows that the type of land use is a major factor in phosphorus concentrations and resultant loadings. The S-2 and S-3 tributary areas have drainage density indices which unquestionably are far larger than those which have been calculated for the lower Kissimmee Valley. However, in the lower valley the type of land use is predominantly oriented toward animal-culture; beef cattle pasture throughout, with dairy operations at the southern extremity. Consequently, with the type of agricultural land use being basically the same, drainage density provides a valid general indicator of phosphorus concentrations. It should be kept in mind, nevertheless, that given the same drainage density, greater phosphorus loadings can be expected from a dairy operation in comparison with a beef-cattle operation due to the greater animal density in the former case and the wider dispersal of animals in the latter case.

These Kissimmee Basin water quality data clearly indicate the following:

1. Man's activities in the Upper Basin (upstream of S-65) at present do not contribute to whatever enrichment problems may be present in Lake Okeechobee.

2. Man's activities in the Lower Basin upstream of Structure S-65C at present contribute little to whatever enrichment problems may be present in Lake Okeechobee.

3. At present the major contribution of enrichment to Lake Okeechobee in the form of phosphorus from the 2,320 sq. mi.* Kissimmee Basin derives from the 220 sq. mi. area contributory to the S-65D and S-65E pools of C-38, and the 35 sq. mi. area entering downstream of S-65E from the east; together a little more than 10% of the entire drainage area.

*Note: Excludes the Lake Istokpoga area.

Focusing attention on this 255 sq. mi. area, using values derived by Heaney and Huber in Phase I of their report "Environmental Resources Management Studies in the Kissimmee River Basin", prepared under contract with the District, we can expect this area to produce an average annual runoff of 12 inches with the present land use. This is approximately 160,000 A.F., annually. This is about 80% of the runoff generated in the 1973-74 study period from the Taylor Creek/Nubbin Slough area, an area of generally similar land use.

Using an average phosphorus concentration of 0.30 mg/1, the annual loading from this area to Lake Okeechobee would be approximately 65 tons. In the 1973-74 study period the total Kissimmee River loading was 117 tons of phosphorus with 1.017 MAF of runoff.

This 255 sq. mi. drainage area, therefore, could be expected to produce 56% of the total phosphorus load from the Kissimmee Basin with only an estimated 16% of the total runoff. Using the same "effectiveness" index as was used to evaluate the relative potential productiveness of nutrient removal measures for tributaries to Lake Okeechobee, an index of 3.50 is derived for this area. This number is almost identical to that derived for the Taylor Creek/Nubbin Slough area.

It seems clear that, in the Kissimmee Basin, immediate attention must be focused on this comparatively small area; such attention having the potential of producing the most effective results in terms of Lake Okeechobee enrichment.

CHANDLER SLOUGH - WATER QUALITY AND FLOW

Because of the high observed phosphorus concentrations of the water entering C-38 from Chandler Slough, the District initiated an intensive study in the lower end of this drainage system. The upper reach of the Chandler Slough drainage and the Cypress Creek drainage (49 sq. mi. and 67 sq. mi. respectively) join together 3.5 miles east of C-38 and from that point flows from both drainage areas move toward C-38 across a marsh having an average width of approximately 2,300 feet and an area of about 1,000 acres.

Intensive sampling runs, involving the quality of the water both entering and leaving the marsh, were conducted during the wet season of 1974 and the following dry season. Wet season flow rates at the upper end of the marsh approximated 400 cfs; dry season flow rate was less than 50 cfs.

Dye studies were conducted in order to approximate the rate of water flow through the marsh and, from these, to estimate the water retention time on the marsh; that is, the length of time the inflow water was exposed to the nutrient assimilation mechanisms of the marsh. For the observed discharges the retention time was estimated to be about 3 days.

The marsh impact on water quality was monitored in July and September, 1974. On these occasions the total phosphorus concentrations were reduced from 0.64 mg/1 to 0.49 mg/1, and from 0.30 mg/1 to 0.14 mg/1; a 25% and 55% reduction respectively. It is clear that nutrient assimilation, the extent of which is dependent upon flow rate and amount of vegetation, is taking place in this segment of marsh. The assimilation rate (lbs P/acre of marsh/day) is not known. Nevertheless, the data at hand are sufficiently convincing to permit a qualitative judgment to be made that this segment of marsh is active in treating the highly-enriched waters which are generated in the upstream watershed.

The data from this study point to a way in which to address the phosphorus enrichment question of the lower reaches of C-38 on which attention was focused as a result of realistically considering and evaluating the water quality data from the entire Kissimmee Basin.

APPENDIX C

BRIEF HISTORY OF LAKE OKEECHOBEE REGION *

Ironically, the United States' oldest frontier, the lowlands of South Florida of which Lake Okeechobee forms the liquid heart, was one of the last regions of the country to be explored and settled. The Calusa Indians, who inhabited the region stretching from the southwest Gulf Coast inland to encompass the Okeechobee region, met the Spanish explorers with such determined hostility that after several encompasses and the death by Calusa arrow of the famous conquistador Juan de Ponce de Leon, Spain decided for the moment, that South Florida, guarded along the southeastern coast with equal vigilance by the Tequesto Indians, was simply not worth the blood price its Indian inhabitants exacted.

In 1566, the Spanish conquistador Pedro Menendez de Aviles brought the Okeechobee region at least nominally under the influence of Spain, by marrying the sister of the fearsome Calusa Chief Carlos. Menendez searched in vain for Lake Okeechobee, then known as Lake Mayaimi, to investigate the possibility of a waterway across the peninsula. He did not find it and no permanent changes resulted from Spanish dominion in South Florida.

As late as 1837, the map-maker Angelo Heilprin asserted that the Okeechobee region was, in many respects, nearly the least-known part of the United States, and that not a single map represented with even approximate correctness the contours of the lake. It was not until Zachary Taylor led 1,067 American soldiers into the Kissimmee River Valley in pursuit of a much smaller band of Seminoles that whites laid eyes on that mysterious and beautiful country. On Christmas Day, 1837, near the northeast shore of Lake Okeechobee, the Seminoles turned to extract heavy payment from the pursuing whites. News of the six dead and one hundred twelve wounded was relayed north and brought Lake Okeechobee, for the first time, into the active awareness of the United States populace.

By 1841, the U.S. Army, Navy, and Marines were operating on Lake Okeechobee. The Seminole was banished further southward into the Everglades and the whites were busy discovering ways to exploit the rich but fluctuating environment of the Okeechobee region. In the early years, the scattered white population earned a living in two distinct ways; raising scrub cattle on the open range, and killing the vast numbers of wading birds for plumes and alligators and mammals for hides. Cattle were shipped from Tampa to Cuba in the 1850s and by the beginning of the Civil War, the Kissimmee Valley and vast areas west of Lake Okeechobee were being used for open-range cattle grazing.

In 1850, Florida received title under the federal "Swamp and Overflowed Lands Act", to some 20,000,000 acres of submerged lands along with 500,000 acres of public lands. Most of this land was located in the Okeechobee Basin. This act, combined with the unparalleled industrial expansion in the North after the Civil War were quickly to bring about startling changes in the Okeechobee Basin.

The Trustees of the Internal Improvement Fund (IIF) was the State agency designated to manage public lands received from the federal government. By 1871, in a climate of rampant corruption, the Trustees had fraudulently sold or given away more land than the State owned, the vast majority going to State officials and railroad and canal company officials. On June 1, 1872, the Internal Improvement Fund was placed under receivership by a federal court for failure to pay overdue bonds. In the short span of 20 years, the IIF squandered most of the 20,500,000 acres of State lands and was bankrupt and in receivership.

The State sent land salesmen around the world in a frantic search for an angel to buy enough submerged land to bail the IIF out of bankruptcy. In 1881 Hamilton Disston, a wealthy Philadelphia capitalist, contracted to purchase 4,000,000 acres in the Okeechobee Basin for twenty-five cents per acre and was promised, in addition, one half of all other lands he could drain. The process of drainage and development in the basin was thus begun, not by the State or any other body with responsibility to the people, but true to the spirit of the times, by a wealthy capitalist bent on maximizing personal profit. Disston assembled a dredge at Fort Myers which ascended the Caloosahatchee River to dredge and dynamite its way into Lake Okeechobee. Without study or forethought, the process of drainage and disruption of one of the most unique and highly integrated ecological systems of the world was set in motion.

The Governor's race of 1905 centered on the drainage of the Everglades, and the elections of Napoleon Bonapart Broward was a decisive event in the subsequent history of South Flordia. It is completely possible that, with careful study and forethought,drainage systems could have been conceived and implemented to drain for farming progressive units of the rich mucklands of the northern Everglades without the great soil losses and other enormous ecological destruction that, in fact, has occurred. Broward was elected, however, on a platform that advocated drainage of the entire region at one stroke by an immense system of canals. As a result of progress towards this end during Broward's term, the State eventually threw its full support behind the scheme and pursued it to its present conclusion.

In 1901, dynamite was put to the limestone ridge that formed the rapids of the Miami River and in 1910, a ten-foot-deep channel extended about four and a half miles into the Everglades, severing an artery that allowed freshwater of the Everglades and the underlying Biscayne aquifer to flow to the sea. Freshwater springs along the shores of Biscayne Bay at Coconut Grove ceased to flow, and saltwater began to move inland. Everglades lands south of Lake Okeechobee were sold to promoters with the Internal Improvement Fund pledge that, upon payment, canals would be constructed, running south, east and westward to drain the lands.

High-pressure salesmen hawked Everglade lands around the country and the world. Excursion boats loaded with

*Abstracted from the introduction to the book: *John Kunkle Small's Florida; From Eden to Sahara, Florida's Tragedy*, edited by Curry Hutchinson, now in manuscript.

fortune seekers plied the freshly dug canals and farms appeared. The first of many debacles soon occurred.

Owing to mineral deficiencies of Everglade muck, crops failed and many Glades farmers were ruined and left Florida impoverished. The land companies simply picked up back tax payments on abandoned lands and sold them again as the boom continued. The IIF felt constrained to state that they had nothing to do with the extravagant promises of land companies, while agreeing at the same moment to dredge two hundred miles of canals in the next three years. The legislature passed an act enabling the bonding of local drainage districts.

This initial drainage occurred during a drought period. When the cycle shifted and a wet year came, most Everglade farmers were flooded out and financially ruined. Scandals were rampant and several land company officials were arrested in other states. When things calmed down, the land companies again picked up the abandoned lands and the boom went on.

In 1915, a contract was signed for a twenty-five mile canal connecting the St. Lucie River with Lake Okeechobee in order to drain water directly east to the Atlantic Ocean. Events quickened; sugar cane was planted south of Okeechobee and sugar mills were barged up the canals into the interior. The state built the Everglades Agricultural Experiment Station at Belle Glade and discovered that muck soil lacks copper and other trace elements. When these elements were added, cane farmers harvested huge yields.

The Glades entered another dry cycle, causing drained Everglades mucklands to oxidize, shrink, and burn under the subtropical sun. Sawgrass was cleared by burning and few cared how far the flames raced or that the dry organic soil itself often burned down to limestone bedrock.

The Everglades were turned into a smoldering inferno while water from Lake Okeechobee flowed sluggishly through the canals to the ocean. When the wet-dry cycle shifted again, townsmen around the lake traveled their streets by boat. Many additional farmers were ruined and left Florida; others hung on. A muck dike was constructed around the southern lakeshore eastward from Moore Haven. When the water receded, crops were planted again.

The 1926 hurricane caused great destruction in South Florida, killing more than 100 people in Miami, blowing water out of Lake Okeechobee and drowning over three hundred Everglade farmers. It also resulted in a reassessment of Everglades' drainage practices. By 1927, fourteen million dollars had been spent on five canals which were incapable of enough drainage during the wet-season to allow farming, but in the dry-season these canals drained the land to bedrock. Even at this late date, no one had studied the Everglades, no one in power had any understanding of what was being done. By 1928, some $18,000,000 had been spent for drainage and land prices were up to $92 an acre. Railroads reached to Okeechobee, and there were 48,000 people in the small settlements and farms surrounding the lake. Total value of Everglades lands was estimated at $106,000,000, 1928 dollars.

In the fall of 1928, a second great hurricane entered Florida at West Palm Beach, moved inland and crushed nearly every human artifact in the Okeechobee region, killing some 1,836 people and injuring 1,870. Storm winds again blew much of the water out of Okeechobee causing extreme flooding south of the lake. As a result, the state, with federal aid, built a vast dike along the eastern, southern, and western lake perimeters, with canal gates for drainage. A new canal to the headwaters of the Caloosahatchee completed what Hamilton Disston began in 1882, and dropped Okeechobee's water level five feet at one stroke. Fields near the Caloosahatchee dried to powder and ground water levels reportedly dropped seven feet. Cypress trees along the Caloosahatchee died from salt water intrusion and wells near the river became salty. Alert people began to doubt that this was what was needed. None the less, in 1929, a new governor was elected with yet another tenuous drainage scheme that consisted of new canals east and west from Lake Okeechobee with a great levee to be built along the southern shore.

Cultivation again began around the lake. It became apparent that muckland farming requires more capital than most individuals could command. Large corporations moved in as the final wave of broken yeomen farmers moved out. Drainage, it was felt, was finally completed and successful. The lake could no longer flood the Everglades. Trainloads of winter vegetables moved north and huge sugar cane farms developed, along with seemingly endless droughts, raging fires, muck oxidation, saltwater intrusion, development of wide, shallow subsidence valleys along each canal in the muck soils, increased frost damage caused by the loss of temperature- buffering waters of the Everglades, great loss of wildlife, and various other symptoms of severe mismanagement of the ecosystem. By 1930, the destruction of the northern sawgrass Everglades was complete.

In 1930, the federal government became involved in the drainage of South Florida. The 1929 Flordia Legislature created the Okeechobee Flood Control District with jurisdiction over 12,000 square miles south of the north shore of Okeechobee. The district was authorized to cooperate with the Federal War Department's Army Corps of Engineers in drainage and flood control projects. Consequently, the St. Lucie and Caloosahatchee Canals were enlarged. What remained of the lush beauty of Okeechobee's lake shore was buried beneath a thirty-four to thirty-eight-foot levee built around the southern shore and extended across low areas further north. During construction, the southeastern lake shore was "straightened" and Pelican Bay transformed into farmland. Kreamer and Torry Islands were physically joined and connected to the mainland. The lake settlements were now free of anxiety and began to develop again. By 1930, the east and south sides of the lake were served by railroads, with freight trucked between West Palm Beach and South Bay. The lake became the commercial crossroad between the east and west coast, and Lake Okeechobee was finally under engineered "control".

With great fanfare, a flotilla of yachts left Stuart, March 22, 1937, headed for Lake Okeechobee through the St. Lucie Canal and then into the Caloosahatchee Canal and on to the west coast, the first boats through the Cross-Florida Waterway. The transecting of the Peninsula by canal, one of

the oldest and most persistent dreams of Florida developers, was a reality.

Belated research by the Federal Soil Conservation Service discovered that twenty-eight percent of the Everglades Drainage District was not suited for agriculture and approximately twenty-two percent was of doubtful value because the muck was too shallow for cultivation. The study also pointed out that proper water management was the only means of controlling fires, oxidation and shrinkage of the priceless muck soils.

The average muck depth in the lake region shrank from twelve to six feet between 1914 and 1943, demonstrating that even the best agricultural muck lands have a limited life span. Drained lands that were left uncultivated were destroyed by oxidation and fire faster than cultivated lands, where ground-water was controlled at a higher level for crop growth. By 1970, muck levels had dropped approximately four additional feet.

With the publication of the Soil Conservation Services Report, concepts of land-use optimization, resulting from water conservation and management, began to exert some meager influence for the first time in over fifty years of frantic and massive drainage efforts. Extreme droughts in 1931 and 1945 resulted in further lowering of ground-water levels. When water levels dropped in the Everglades, salt water rose in the wells causing salt intrusion in the water supply of Miami and other east coast cities. The Miami Canal was found to convey salt water to the Miami Springs well field during the 1945 drought, and a saltwater intrusion dam was constructed. Salt water intrusion, raging fires, and muck oxidation were simply the grossest symptoms that the ecosystem was under reoccurring stress from over-drainage, general management, and abuse.*

The Everglades Drainage District recommended, in 1946 and 1947, the creation of three water retention areas south of the farming district in what was drained Everglade lands to keep land in that area wet and thus protected from oxidation and fire until needed for cultivation. At the same time, the District proposed digging three additional intermediate canals and enlarging existing canal outlets. The legislature failed to act on the proposals.

In June of 1947, the Corps of Engineers held a public hearing at Belle Glade to present their "water control" plan for South Florida. They proposed to construct levees and canals in the 920-square-mile Agricultural Area, south of which they planned vast Water Conservation Areas similar to those proposed earlier by the Everglades Drainage District. Canals already built were to be "improved" and two new canals dug. The Kissimmee River was scheduled for canalization.

The wet-season of 1947 was the wettest in seventeen years and in September, a hurricane entered the peninsula near Ft. Lauderdale and crossed to Ft. Myers. Lake Okeechobee, although not in the direct path, experienced heavy rains and high winds. The levee held, making unnecessary the great migration from surrounding areas led by people who remembered well the storms of 1926 and 1928. Daily rains continued, and two additional storms occurred within a month of the hurricane. The Caloosahatchee Canal and Fisheating Creek went overbank, and the Kissimmee River floodplain was under water. Water began to flow southward across the land as it always had, now going eastward around the great man made lake levee, crossing the highway east of Canal Point, breaching farm levees and going on south into what remained of the Everglades. Water immediately west of Miami stood 6 to 8 feet deep for vast distances. The western suburbs of West Palm Beach, thirty percent of Ft. Lauderdale, and large areas of western Miami, Miami Springs, and Hialeah were inundated. Drainage again became the cry.

In December of 1947, the Corps of Engineers submitted a report stating that "the problems of flood protection, drainage, and water control were considered to be physically interrelated, and that the St. Johns, Kissimmee, Lake Okeechobee, Caloosahatchee, and Everglade Drainage areas all formed a single economic unit." They recommended a program of "flood control, drainage, and related purposes."

The governor approved the report and the 1949 Legislature created the Central and Southern Florida Flood Control District to succeed the Everglades Drainage District and the Lake Okeechobee Flood Control District and deal with the Corps and other federal agencies in drainage and flood control matters.

Over the past two decades the entire basin has experienced increasingly accelerated urban development along the coast and agricultural development in the interior. Remaining natural values have been greatly degraded or destroyed and the problems of water pollution and water shortages have become endemic and critical.

Subsequent construction included a levee running from Lake Okeechobee southward to just north of Homestead in south Dade County, walling off the urbanizing east coast from the Everglades. A number of new canals were dug, existing canals deepened and widened, the levee around the Agricultural Area south of Lake Okeechobee constructed, and the 1,340 square miles of Water Conservation Areas in western Palm Beach, Broward and Dade Counties were diked. Immense pumps were installed to pump water from the Agricultural Area south into the Conservation Areas, and north into Okeechobee. The levee around Okeechobee was heightened and expanded, completing the encirclement of the 730 square mile lake.

With channalization of Taylor Creek by the Soil Conservation Service, canalization of part of Taylor Creek and all of the Kissimmee River by the Corps of Engineers in the 1960's, and construction of water control structures between several of the Kissimmee Upper Chain of Lakes, the entire Okeechobee Basin, extending from South Orlando to Florida Bay, came under varying degrees of engineering control for essentially the single purpose of drainage, with

*Parker, Gerald G., et al., 1955. *Water Resources of Southeastern Florida.* U.S. Geological Survey Water-Supply Paper 1255, 965p., Washington, D.C.

minor flood control benefits. Napoleon Broward's dream of turning South Florida into a prototype Holland had come true.

The Flood Control District, armed with Ad Valorem Taxing authority, and the Corps of Engineers have now expended approximately 529 million dollars, constructed thousands of miles of canals, and levees, and completely changed the physical and ecological characteristics of South Florida. The total budget of the Central and Southern Florida Flood Control District for recent years, approximates 18 million dollars per year.

Entrance of the Corps of Engineers and the Soil Conservation Service into drainage of South Florida in the late 1940's signaled the beginning of an era of large-scale public works supplanting piecemeal local and state efforts. In the Okeechobee Basin, massive drainage, diking, and canalization projects by the Corps and the canalization of small watersheds by the Soil Conservation Service has confined water flows to ever decreasing areas, enabling farming and development in large areas that were formerly natural floodplains during the wet season. Rich wetland systems, formerly enriched by seasonal waters, were drained and developed. In the Kissimmee River Valley, the natural drainage ratio of much less than one mile of surface drainage course (natural creeks, sloughs, etc.) per square mile of land area had, by 1972, been increased to 20 miles of surface drainage courses (channelized creeks and ditches) per square mile for urban areas, 12 miles of surface drainage courses per square mile for citrus and vegetable farming areas, and 5 miles per square mile for pasture.* Nutrients and pollutants from these developed areas now travel through thousands of miles of privately constructed ditches and canals directly into canals and canalized rivers of the Flood Control District system that are not biologically capable of assimilating large waste loads. In addition, massive doses of secondarily treated sewage are injected into some lakes and canals. Millions of acres of upland wetlands, that formerly kept water quality and fish and wildlife populations high and stored water through all but the most severe dry seasons, have been drained. In the Kissimmee River Basin along, from 1958 to 1972, some 138,000 acres of swamplands were drained.** These wetlands which should have been protected and utilized to store and treat low quality runoff waters from upland farms and cities, have now been drained and developed to produce still more runoff that travels swiftly in canalized "pipeline" ditches such as Canal 38, formerly the Kissimmee River, and Taylor Creek, direct to Lake Okeechobee, itself now diked into a system resembling a huge sewage polishing pond, and suffering from cultural eutrophication.

*Heaney, James P., Huber, Wayne C., et al., 1974. Environmental Resources Management Studies in The Kissimmee River Basin, Phase I. Department of Environmental Engineering Sciences, University of Florida, Gainesville, Florida.

**Op Cit.

APPENDIX D

DEPARTMENT OF POLLUTION CONTROL'S STATUS REPORT ON THE KISSIMMEE RIVER–LAKE OKEECHOBEE SPECIAL REPORT

INTRODUCTION

The Special Project to Prevent the Eutrophication of Lake Okeechobee was founded primarily to check the further deterioration of the lake, perhaps the most significant body of fresh water in the State of Florida. As these waters serve as a public potable water supply, are necessary for a large portion of the agriculture in the central and southern portion of Florida, and are utilized in an active commercial tourism, any further degradation of this valuable natural resource must be prevented.

The available data indicate that the alteration and deterioration of the Kissimmee River-Lake Okeechobee watershed is primarily due to the maldistribution of nutrients. In agreement with this approach, the Department of Pollution Control has instituted a basin-wide identification, examination, and evaluation of pollution sources. With these goals accomplished, the Department will then attempt to alleviate those conditions allowing for the degradation of waters in the basin. The present project includes the analysis of both point and non-point sources of pollution, and also involves an intensive study of possible pollution abatement measures and the environmental effects of various land usage patterns, channelization, marsh drainage, river impoundment, and unnatural discharge of natural waters.

POINT SOURCES

Generally speaking, there are three types of point sources under investigation: industrial, municipal sewage treatment plants, and private sewage treatment plants.

Municipal plants are the dominant surface dischargers, particularly in the Upper Basin, and the fifteen municipal plants discharging in this manner have been found to account for more than 70% of the over 2.5 million pounds of N and 1.5 million pounds of PO4 (as P) loading the basin from all point sources each year. Furthermore, more than 200 private STP's for mobile home parks, small subdivisions, and campgrounds (mostly in the Orlando area) discharge significant quantities of wastes into percolation-evaporation ponds and/or drainfields. In addition, several point sources on the perimeter of Lake Okeechobee may discharge directly into the lake during periods of high precipitation and rising water levels.

Several alternatives to discharge of wastes to surface waters are being evaluated - advanced waste treatment with hi-rate recharge, deep well injection, and land spreading. At present, deep well injection is not a proven alternative, and will remain as such until suitable tests are performed. Land spreading may possibly be the most effective method for the control and treatment of point source additions, and a brief over view of the feasibility of this method, along with a study on the public health aspects, will be presented in the final report.

A third aspect of the point source program includes a groundwater hydrology study. This groundwater sampling program will assist in the delineation of major aquifers and their influence on surface waters. It is significant that the Florida Aquifer has been a recipient of Orlando's urban run-off for at least 30 years and that, during periods of low surface flow, groundwater may affect the quality of surface waters through seepage and spring intrusion. Currently, four wells in Orange County and three in Osceola County, where groundwater is becoming an important part of the annual water budget, are being sampled for several parameters including specific conductivity, silica, potassium, total dissolved iron and total organic carbon, as well as nitrogen and phosphorus series.

NON-POINT SOURCES

Much of the alteration and degradation of natural waters in the United States is now recognized to be caused by non-discrete and diffuse sources of pollution, i.e., non-point sources. It is probable that the principal additions to Lake Okeechobee and the Kissimmee River (C-38) are from non-point sources and not from more readily defined and easily evaluated point sources.

One major form of non-point source pollution, urban run-off, has gained recognition as a major source of pollution. Impervious surface paving causes increased surface run-off which, during the first hour of a major storm, delivers very high pollutant loads to receiving waters: including high levels of BOD, coliforms, suspended solids, and nutrient concentrations, as well as heavy metals, chlorinated organics, organophosphates, and polychlorinated biphenyls (PCB's).

The principal urban area in the Kissimmee Basin is Orlando, of which about 35% of the total metropolitan area contributes run-off to this basin, while the remainder of Orlando drains into the St. Johns River Basin. In our current program the questions pertaining to amounts of run-off and concentrations remain theoretical as no urban run-off sampling has yet been accomplished. However, the Orange County Pollution Control Department has initiated such a study, and by consulting this data and considering urban drainage patterns and storm characteristics, nutrient loadings from Orlando will be calculated. Preliminary calculations indicate that urban run-off may be a significant in-put to the Shingle Creek-Lake Tohopekaliga system, since as much as 105 tons of N and 13 tons of P may be added each year to this system or to the Florida Aquifer. In the entire basin, urban run-off appears to be far less of a problem than agricultural run-off. The most practical and efficient abatement strategies are currently under study and recommendations will be forthcoming in the final report.

In order to more fully determine the location and significance of non-point pollution sources, four areas within the Kissimmee River Basin have been selected for intensive

sampling of important chemical environmental parameters. Each area (Shingle Creek, Ice Cream Slough and Blanket Bay Slough, Chandler Slough, and Taylor Creek) has been sampled in several locations on four separate occasions for approximately thirty separate parameters, some of which were measured in situ and others were determined by laboratory analyses. Concurrent with this study is a water-sediment-macrophyte system study to determine uptake capabilities, and nutrient utilization and release within sediments and overlying waters.

Preliminary Results:

Preliminary data analyses substantiate several hypotheses and indicates other heretofore unrecognized trends:

STP loadings in the Shingle Creek area tend to mask loadings from non-point sources, but it has been shown that the natural marshes encompassing several miles of the creek provide important nutrient uptake functions and improve water quality.

Another finding is that there is a significant net increase in non-point source additions between S-65 near Lake Kissimmee and S-65E near Lake Okeechobee, and these NPS's add at least 161,000 pounds/year of total PO4.

Furthermore, the sediment study has shown that an accumulation of highly organic sediment is deposited in the slough systems during periods of low flow and that this load is flushed out into C-38 during the wet season, causing an exceptionally high and abnormal BOD load.

Data comparison among three slough systems (Ice Cream Slough, Blanket Bay Slough, Chandler Slough) indicate the significance of agricultural practices on the magnitude of non-point sources of pollution. Drainage from improved pasture in the basin appears to contain far higher nutrient concentrations than comparable unimproved pasture. As well as calculating loadings throughout the basin, one emphasis of this study is in the investigation and evaluation of dairy practices and abatement measures. Recommendations on present and future abatement procedures will be presented in the final report.

Present Conditions in the Basin:

Biological collections and statistical data reduction have been used in this project in order to quantitatively assess the present ecological situation within the basin. Through the use of these techniques, an analyses of various ecological communities can be made, intermittent pollution documented, or extremely low levels of environmental alteration recognized. Our program includes the Algal Assay techniques and the evaluation of phytoplanktonic, benthic macroinvertebrate, and lower aquatic vertebrate communities.

Laboratory algal assay allows some prediction of future events on the basis of fluctuating nutrient concentrations. Presently, monitoring stations are located in Lake Toho, East Lake Toho, Cypress Lake, Lake Kissimmee, Blanket Bay Slough, Ice Cream Slough, Chandler Slough and several locations in Lake Okeechobee.

Phytoplankton and invertebrate collection data are still being analyzed but fish collections, substantiate some chemical trends, and point out some interesting aspects of ecosystem manipulation. In Shingle Creek, community diversities (a measure of environmental health and stability) increase with distance from STP outfalls, as would be expected, in direct correlation with chemical data. However, Blanket Bay Slough, where water quality is considerably poorer than Ice Cream Slough, still supports a more diverse fish fauna than the latter slough. This is an indication that channelization and its subsequent unnatural high flow - low flow regimes may be very detrimental to ecological communities, since recovery from channelization is far more complete in Blanket Bay Slough. Taylor Creek data are consistent with this trend as those areas showing the lowest community diversities are also those that have been the most altered by channelization. This is an extremely significant point when one remembers that the definition of water quality includes, under PL 92-500, the biological integrity of the water.

Contract Studies:

In addition to the work discussed above, the Department is also contracting out work in a number of important areas (Attachment I). Summaries of the major work elements in the study are appended hereto as Attachment II.

APPENDIX E

MANAGEMENT TRENDS IN CASE ECONOMIC CONDITIONS OF NO-GROWTH EVOLVE

Rapid economic development in South Florida in the last decade was caused by large income and capital investment which the region used to purchase fuel, goods, and services. The resultant rapid growth was based on energy imported to Florida. Prices of fuel from Venezuela and other countries were very low and much work could be obtained from cheap fuels purchased with income money. The abundant natural areas in South Florida were a strong attraction to tourists, retirees, federal projects, and land developments. The free natural energies of sun, water, winds, and land provided free services and amenities that made Florida's economy competitive. Purchased fuel and other energy was matched with substantial energy supplied by natural systems. This made Florida prices, products, and recreation competitive. Areas within the region that used more free natural energy to complement purchased energy grew the fastest.

The cost of money and energy needed to get energy out of the ground has increased over the world. This results in a greater percentage of the world economy going for purchasing energy. Consequently, the net energy obtained by the processing of crude oil decreases which increases the price of the refined energy that results. This was the reason for the Arab oil price increases in 1973 which sharply reduced the amount of energy that a dollar can purchase. The higher price of energy has reduced the amount of money that comes into Florida as tourist money, retiree funds, government subsidies, etc. With less income and much less energy per dollar, the cheap energy stimulus to rapid growth in Florida has been removed. Computer models of the South Florida region, and the economy of Miami and of Lee County, all indicate a decrease in the rate of growth and some decline in economic development as incomes decrease and energy prices increase. It appears that growth in South Florida has leveled.

Some South Florida areas now have little remaining natural areas to supply free energy to attract new development. Areas, such as the Lake Okeechobee area, where urbanization has not been pronounced, still have free natural energies to attract large economic energies. Relative to Miami, therefore, the Okeechobee area is more competitive and thus able to attract investment capital to match its natural free energy subsidies.

South Florida growth may be leveling because of a decrease in total energy and economic activity. Some readjustment in economic activity towards the Lake Okeechobee area may be expected. The present ratio of purchased energy to free natural energy for the entire United States is about 2.5 units of purchased energy to 1 unit of free natural energy when converted to equivalent amounts of work. Growth may stop in a given area when this ratio is reached. The overall ratio should go down as a given amount of purchased energy becomes more expensive and economic activity declines proportionately.

The trends discussed here are given added credibility by calculations and computer simulations. If these trends continue, the pattern of land and water use affecting Lake Okeechobee may be expected to change. Economic activities that are less intensive in fuel consumption and that use a higher ratio of the free energy of sun, water, and land will outcompete activities that use intensive fuel consumption. Some fuel-intensive agriculture should be replaced with agriculture that uses less irrigation, machinery and chemicals, and more land, labor, and local markets. Yields per acre under this system will be less. Economic land use will employ more conservative practices for maintaining soil fertility and water quality. Native range and pastures managed for maximum production with minimum fuel inputs can maintain grass cover, upland fertility, and production, especially if ponds and marshes are used for water regulation and nutrient recycling. Some drainage channels may need to be partially filled to create water levels more conducive to a lower energy agriculture.

Water management on a regional scale will tend to be replaced by smaller water management systems with local retention and local use. Decreasing pressure for water for the dense Gold Coast should occur if there is decline in activity there. The value of using water in the area around Lake Okeechobee would then increase. Canals and pumping regimes may need to be modified to use less energy more effectively. If people without incomes come to Florida there may be opportunities for developing somewhat self-supporting farm cooperatives and homesteading. The productivity of the land and water around Lake Okeechobee may prevent the serious problem of having too many people for the available resources and energy that is available.

MANAGEMENT OF THE LAKE OKEECHOBEE ECOSYSTEM CONCEPTS AND PRINCIPLES*

An ecosystem is composed of parts that work together as a unit. Ecosystems require energy to evolve, produce metabolic waste, and maintain and reproduce themselves. An ecosystem is surrounded by an environment with which it interacts and to which it adapts. Regional ecosystems such as that of South Florida (Fig.1)encompass all biological communities within a region, including man.

The concept of stress** and an ecosystem's response to it are central to ecological management. If man is to manage an area that is subjected to a set of environmental stresses such as South Florida's climatic regime of alternating wet and dry seasons, he must ask: Which is more efficient and cheaper in overcoming environmental stress--the natural system that is already adapted to the stress and programmed to cope with it, or a substitute system designed

*This section is abstracted from Lugo, Ariel E., and Samuel C. Snedaker, 1971. In readings on Ecological Systems: Their Function and Relation to Man. MSS Education Publishing Company, Inc., 19 East 48th St., New York, N.Y. 10017.

**Stress is defined as wear and tear (Selye, 1956) or, said another way, stress is the drain of energy capable of doing work (Odum, H.T. 1971).

and engineered by man?At the turn of the century when South Florida was being drained and settled, no one understood ecological responses well enough to formulate such a question. Massive changes have been imposed with resulting disordering and loss of vital services of the ecosystem and with tremendous management costs for man.

Natural ecosystems cope with stress using free energy from the sun. When man substitutes an engineered system, the environmental stresses still remain. The engineered system must cope with stress using work by man and machine. Fuel and labor costs must be considered when evaluating engineering systems and management techniques. Loss of the free ecosystem work and products, such as water storage, water quality, fish and wildlife, etc., due to stress introduced by man's management must also be considered. Traditional economic accounting considered only short-term profits and has failed to consider the long-term costs of the benefits of nature's free goods and services. In addition, the more processes man distrubs, the less capable the ecosystem is of returning to its natural operations if management is withdrawn.

Ecosystems have many rhythms that express themselves in a variety of cycles ranging from daily to seasonal, annual, and longer fluctuations. These rhythms are responses that have evolved over time to maximize the energy available to that ecosystem. The specific characteristics of the program an ecosystem evolves to maximize its energy is determined by prevailing environmental conditions.

An ecosystem's evolutionary program, as designed by natural selection, is the optimum operating regime for that system. Between maximum and minimum levels, there is a range where that ecosystem can continue to function and it is within these limits that management must operate. For example, the level of water in the ecosystem at any given time of the year can only be so far above or below the optimum that the ecosystem has evolved before stress occurs. Periodic stress rejuvenates certain types of ecosystems and results in a period of increased productivity. Chronic or overload stress, however, drains the ecosystem of its vitality. If continued long enough, death of some of the ecosystem's living organisms ensues. Often when man overloads an ecosystem, and thereby becomes a new and special stress, the ecosystem reacts by changing both its structure and function. As species are lost, the ecosystem switches to another type of ecosystem that is usually less productive but able to adapt to the imposed stresses. The South Florida ecosystem has been in a state of chronic stress. There are unmistakable signs that the regional ecosystem that evolved in South Florida is presently switching to a less productive type ecosystem (Carter et al., 1974) This process seems to be well advanced, although it is much better to maintain natural patterns as much as possible, so that the natural ecosystem can regenerate itself quickly and cheaply after stress.

The key to management success in South Florida is an understanding of the overall adaptations of the region to environmental conditions that prevail there. These adaptations should be used to minimize management costs and the loss of natural productivity. Man must use the South Florida ecosystem for the work it can do best. Reduced management costs will occur because the ecosystem already provides a productive base with which to work. This approach precludes extensive modifications and ensures long-term stability.

The key question pertaining to ecological management is: To what extent and in what manner can man change the ecosystem for his purposes before it becomes subjected to overload stress? In ecosystems like the South Florida regional ecosystem which are already under serious chronic stress, with large-scale changes in structure and functions, the question becomes: How can stress be reduced and natural functions restored so as to stabilize the ecosystem under optimum conditions for man and nature?

In this age of rising fuel costs, man must learn to take maximum advantage of the free work and products of nature. For this, he must manage ecosystems to maximize their health and productivity.